US009843017B2

(12) United States Patent
Yanagisawa et al.

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(45) Date of Patent: Dec. 12, 2017

(54) **DISPLAY DEVICE, MANUFACTURING METHOD THEREOF, AND ELECTRONIC DEVICE**

(71) Applicant: **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa-ken (JP)

(72) Inventors: **Yuichi Yanagisawa**, Kanagawa (JP); **Takuya Kawata**, Kanagawa (JP)

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.** (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 18 days.

(21) Appl. No.: **14/826,585**

(22) Filed: **Aug. 14, 2015**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Aug. 22, 2014 (JP) 2014-169167
Oct. 8, 2014 (JP) 2014-206913

(51) **Int. Cl.**
H01L 27/32 (2006.01)
H01L 51/52 (2006.01)
H01L 51/56 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/5246*** (2013.01); ***H01L 27/3244*** (2013.01); ***H01L 51/524*** (2013.01); ***H01L 51/56*** (2013.01); *H01L 2227/323* (2013.01); *H01L 2251/5315* (2013.01); *H01L 2251/5338* (2013.01)

(58) **Field of Classification Search**
CPC H01L 51/5246; H01L 29/7869; H01L 29/66969; H01L 27/3244; H01L 51/56; H01L 51/525; H01L 2227/323; H01L 2251/5338; H01L 2251/5315
See application file for complete search history.

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Primary Examiner — Asok K Sarkar
Assistant Examiner — Dmitriy Yemelyanov
(74) *Attorney, Agent, or Firm* — Husch Blackwell LLP

(57) **ABSTRACT**

A highly reliable display device. A first flexible substrate and a second flexible substrate overlap each other with an element positioned therebetween. A periphery of the overlapped first and second substrates is covered with a high molecular material having a light-transmitting property. The high molecular material is more flexible than the first substrate and the second substrate. As the element, for example, an EL element can be used.

21 Claims, 58 Drawing Sheets

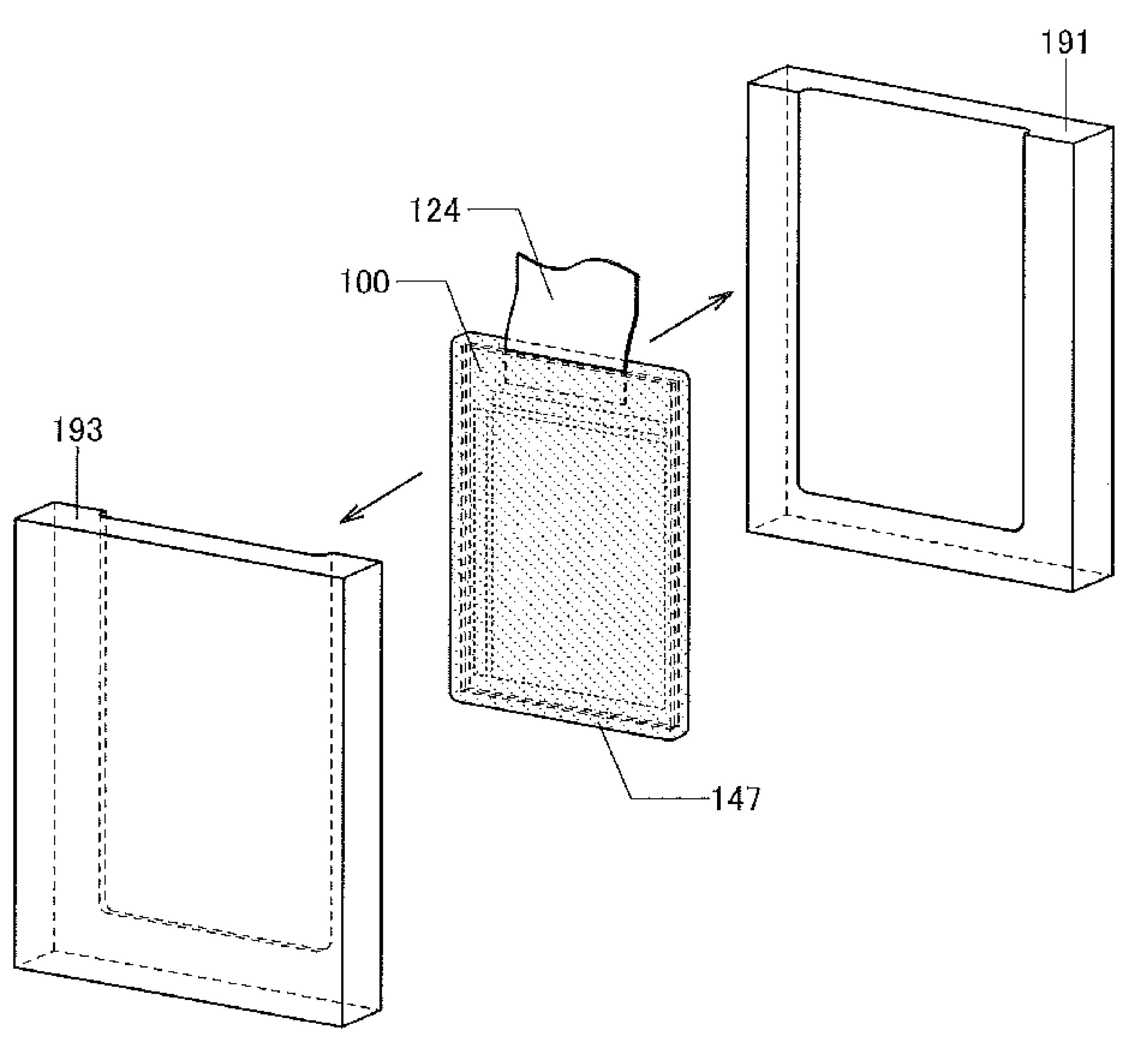

FIG. 1

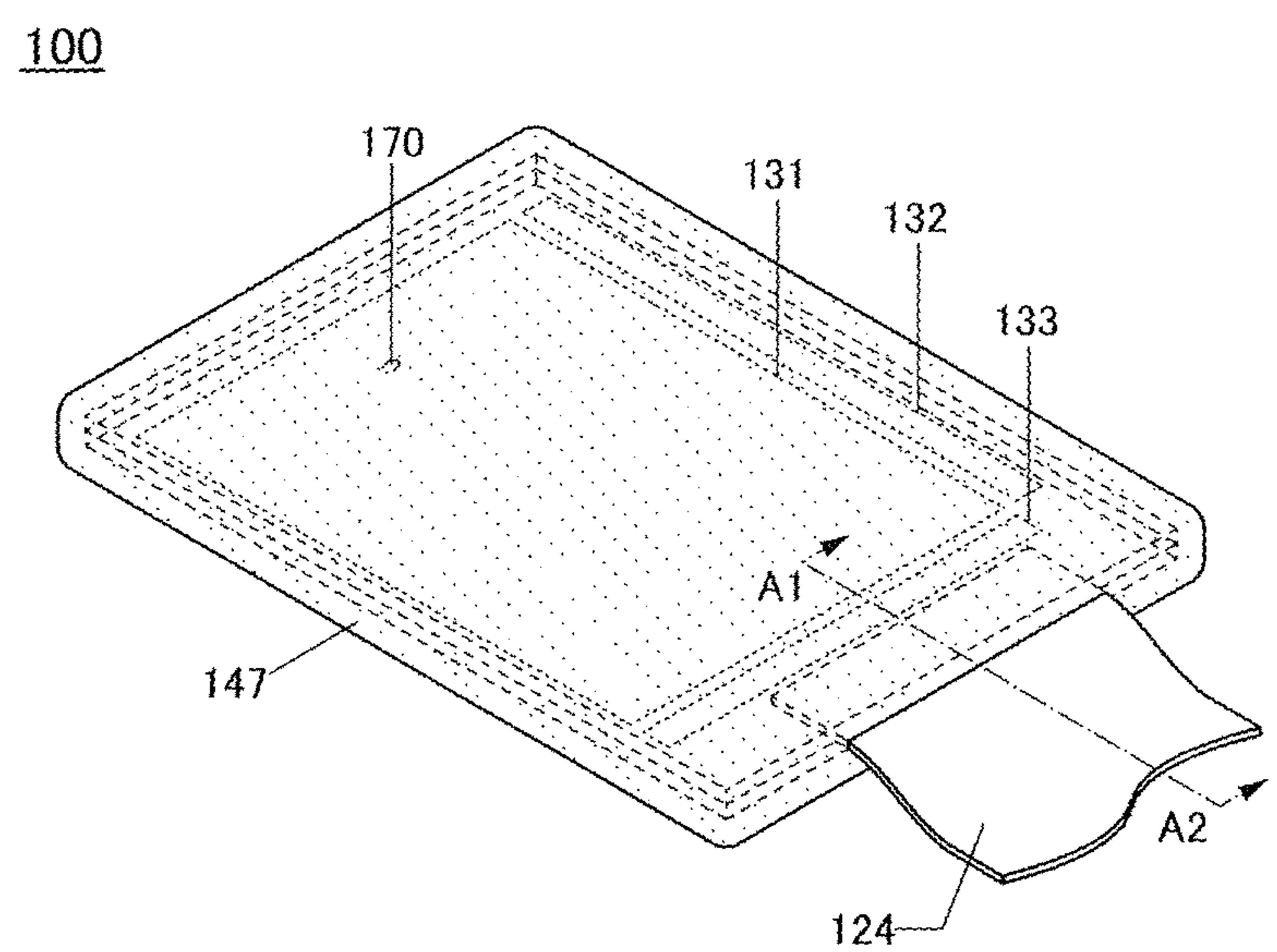

FIG. 2A

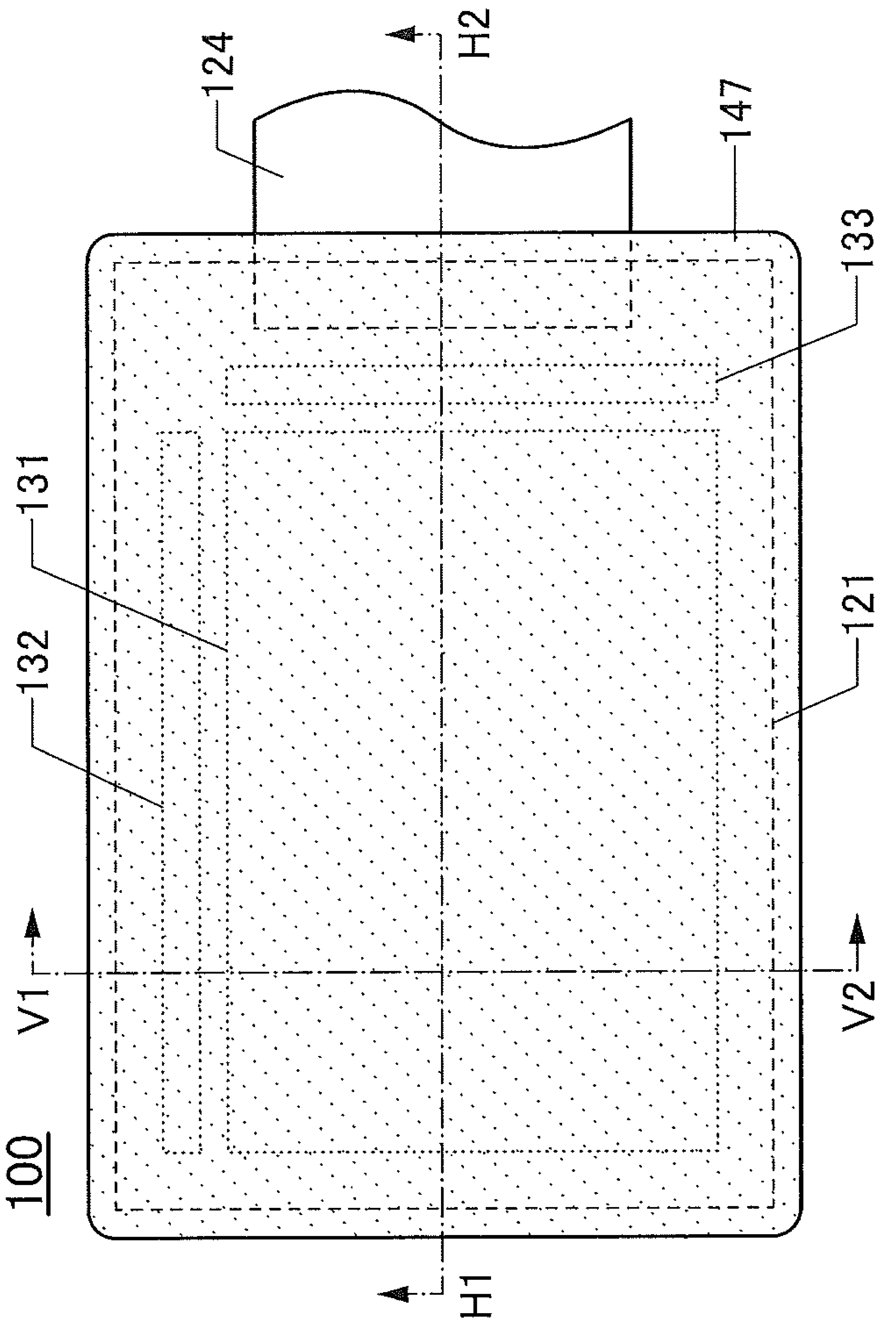

FIG. 2C

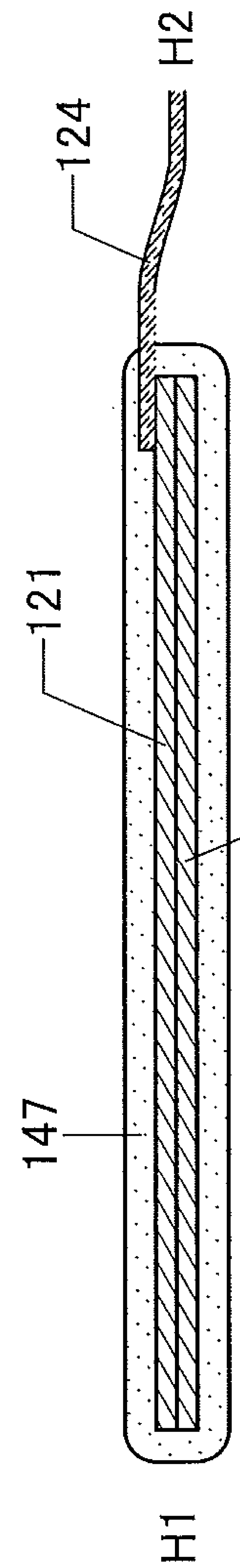

FIG. 2B

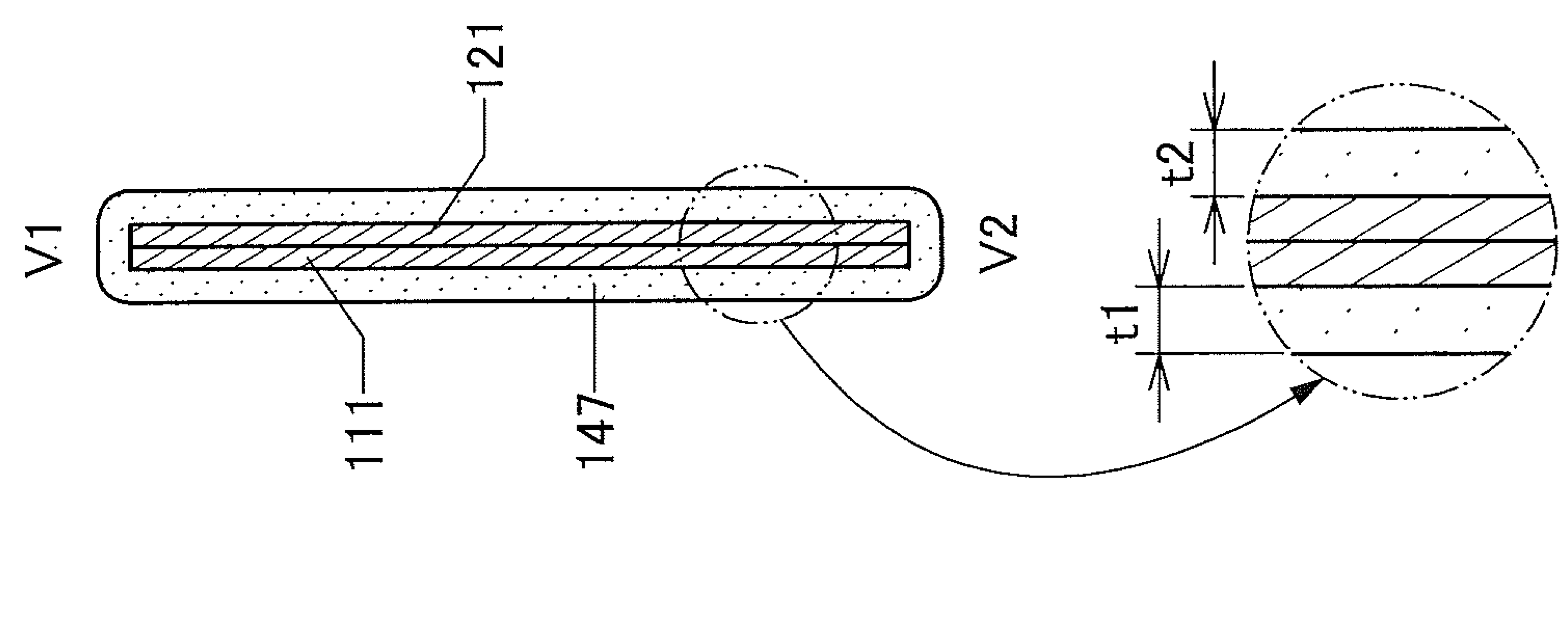

FIG. 3

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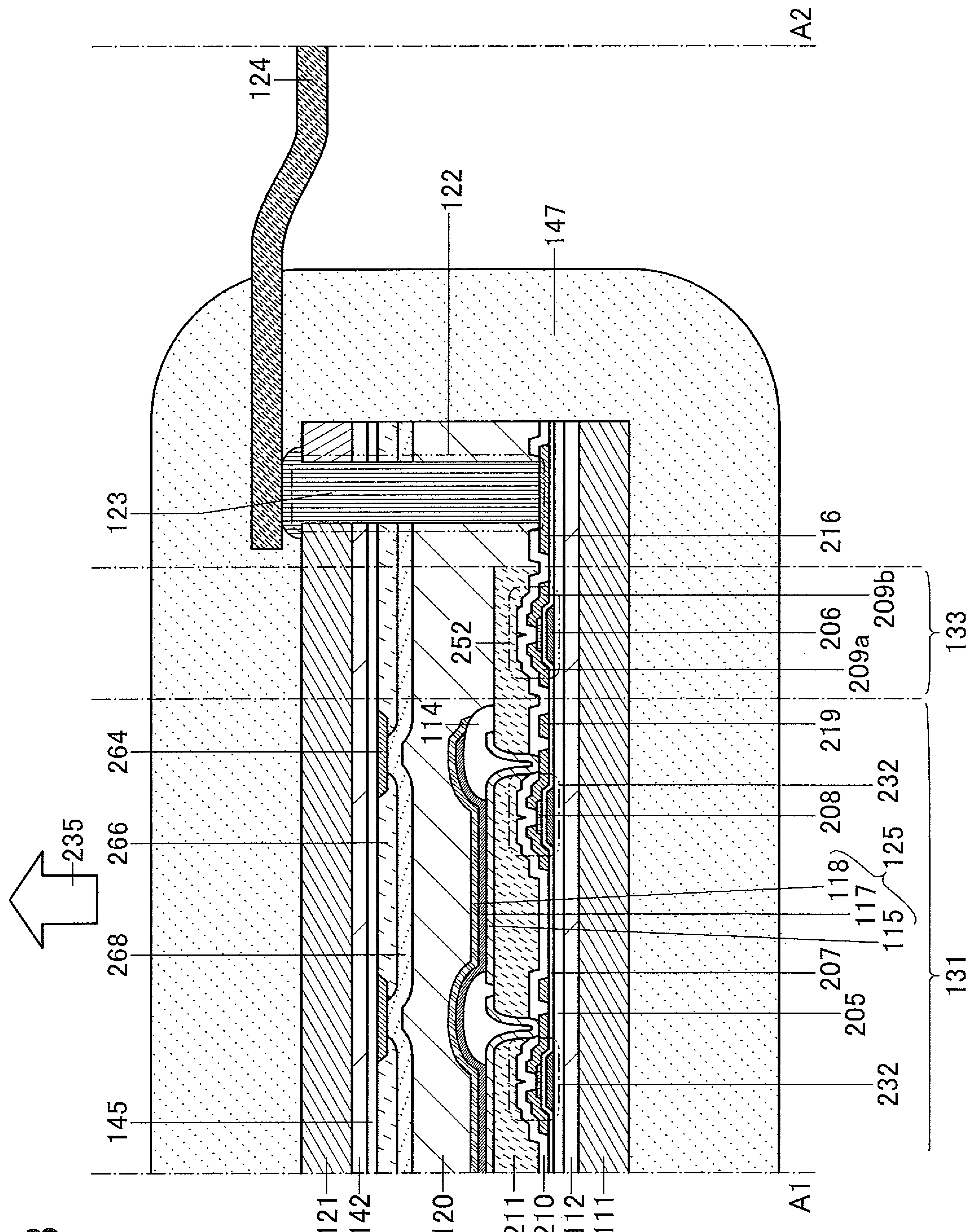
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FIG. 4A

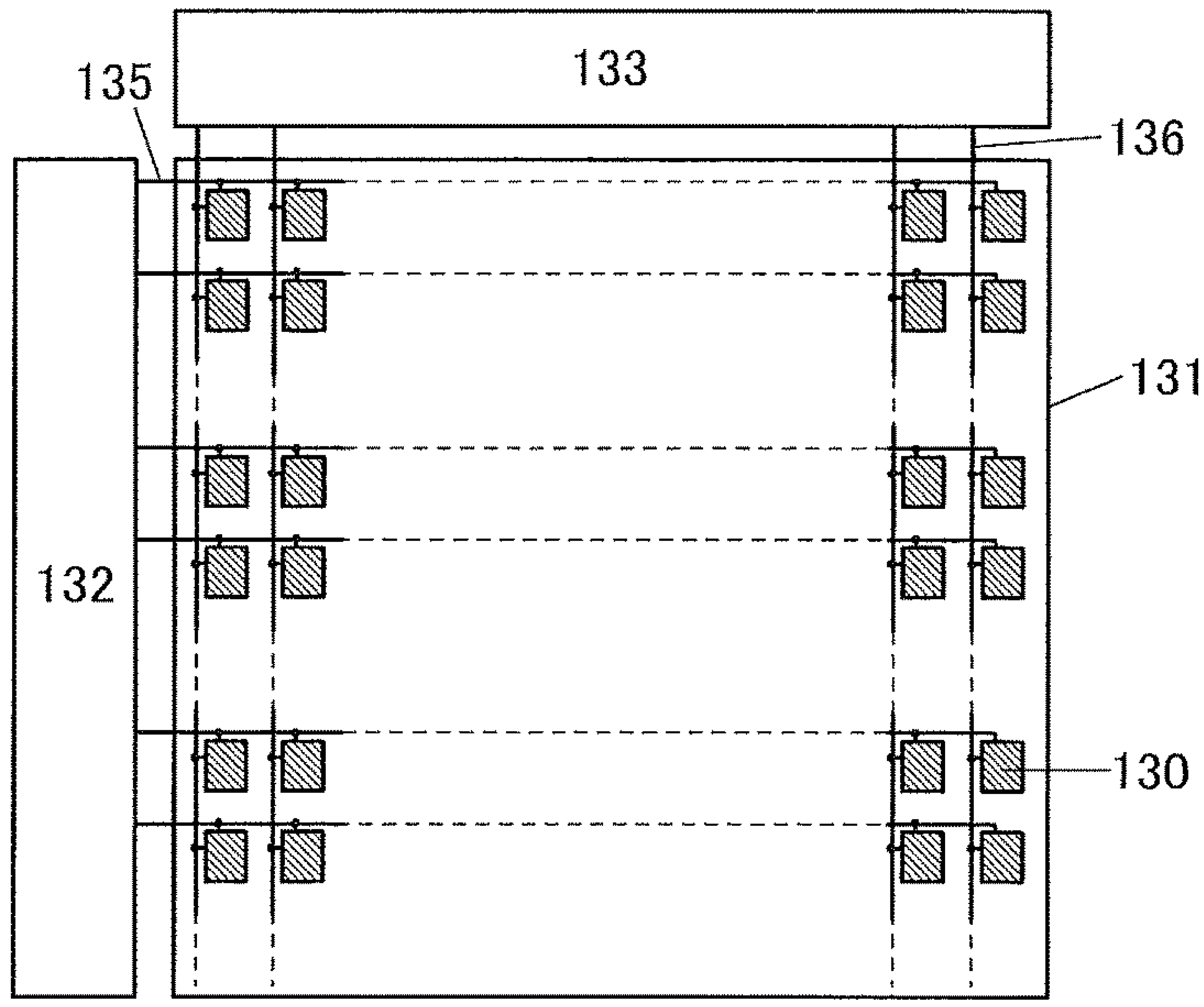


FIG. 4B

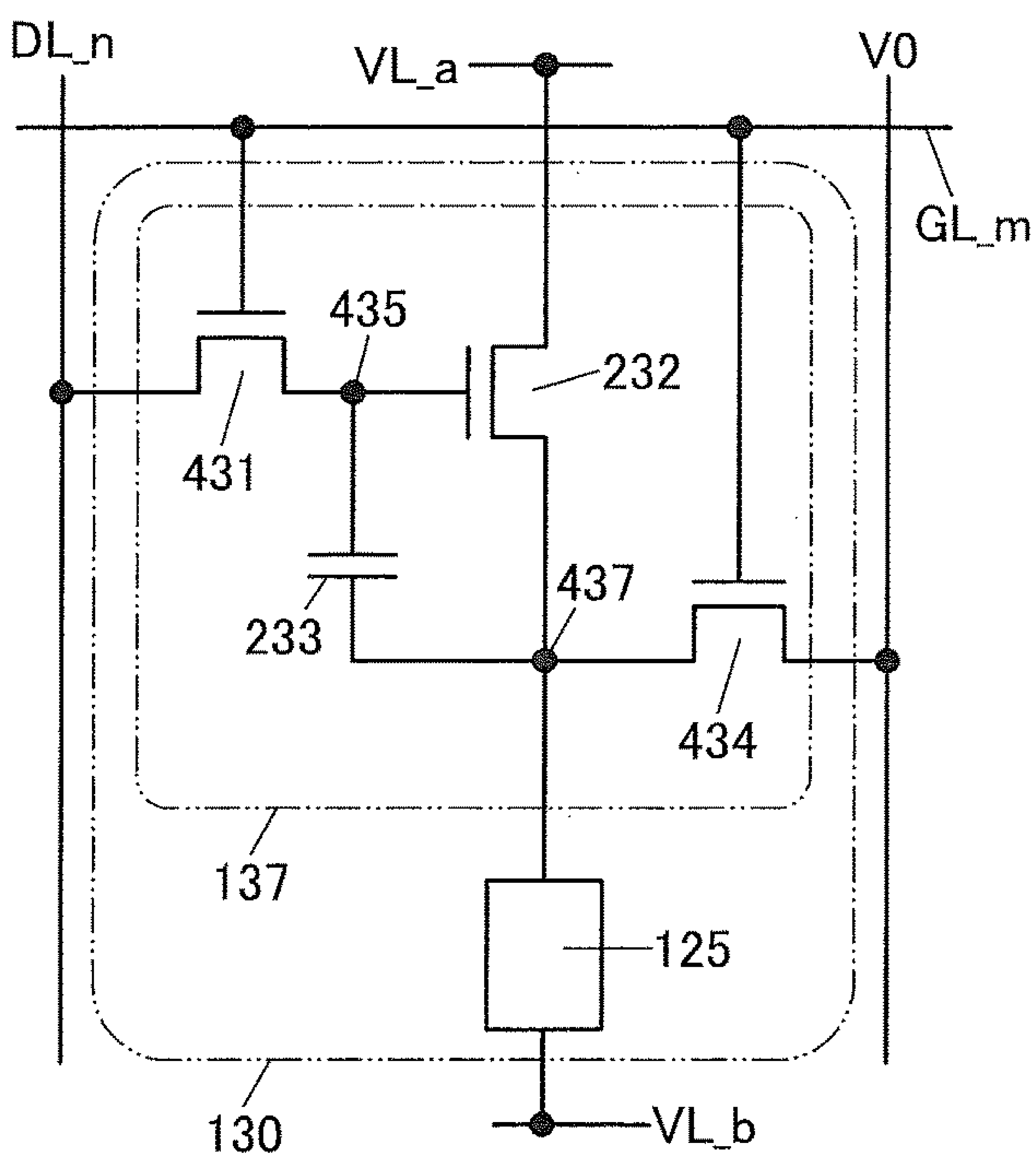


FIG. 4C

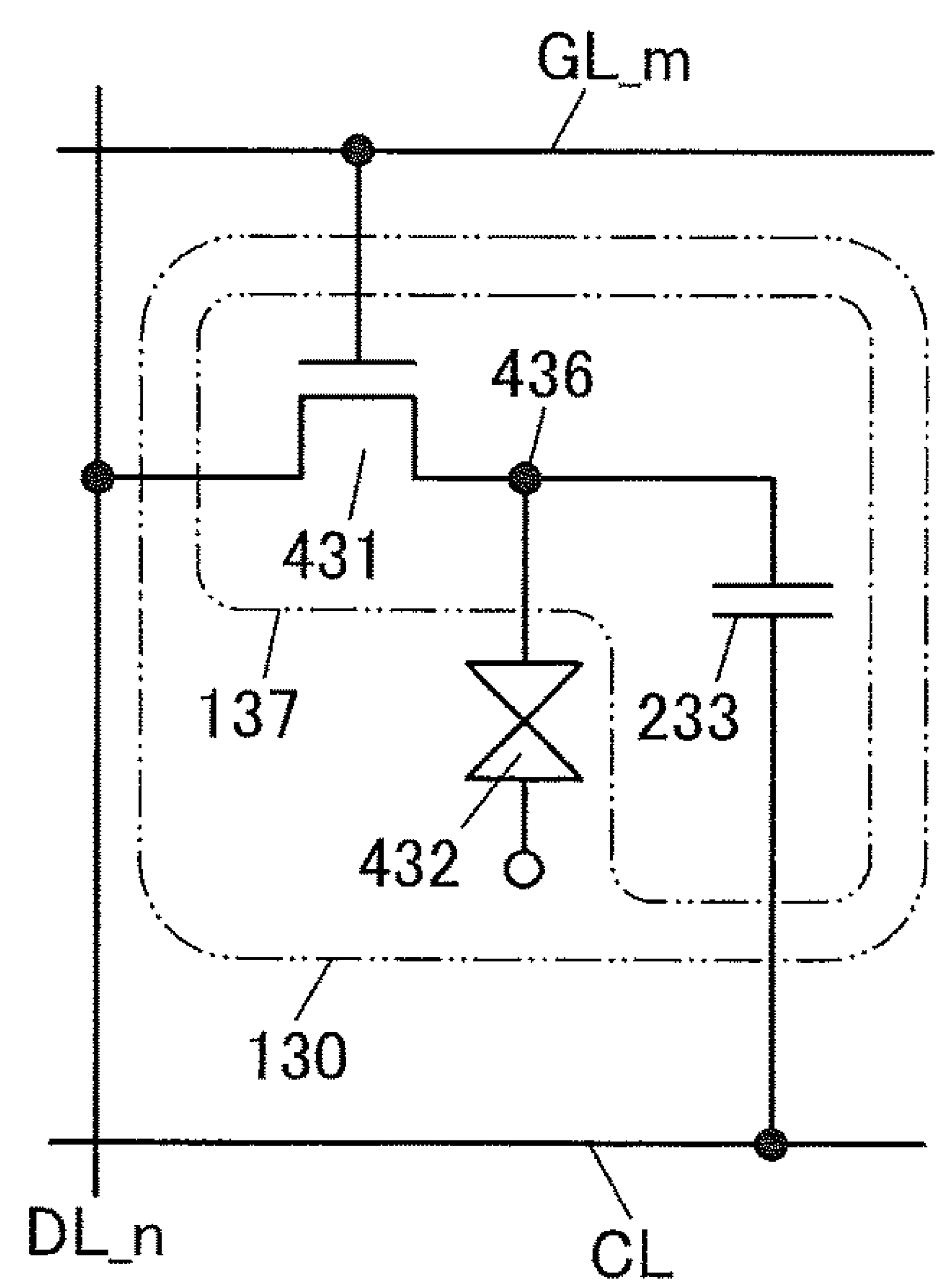


FIG. 5A

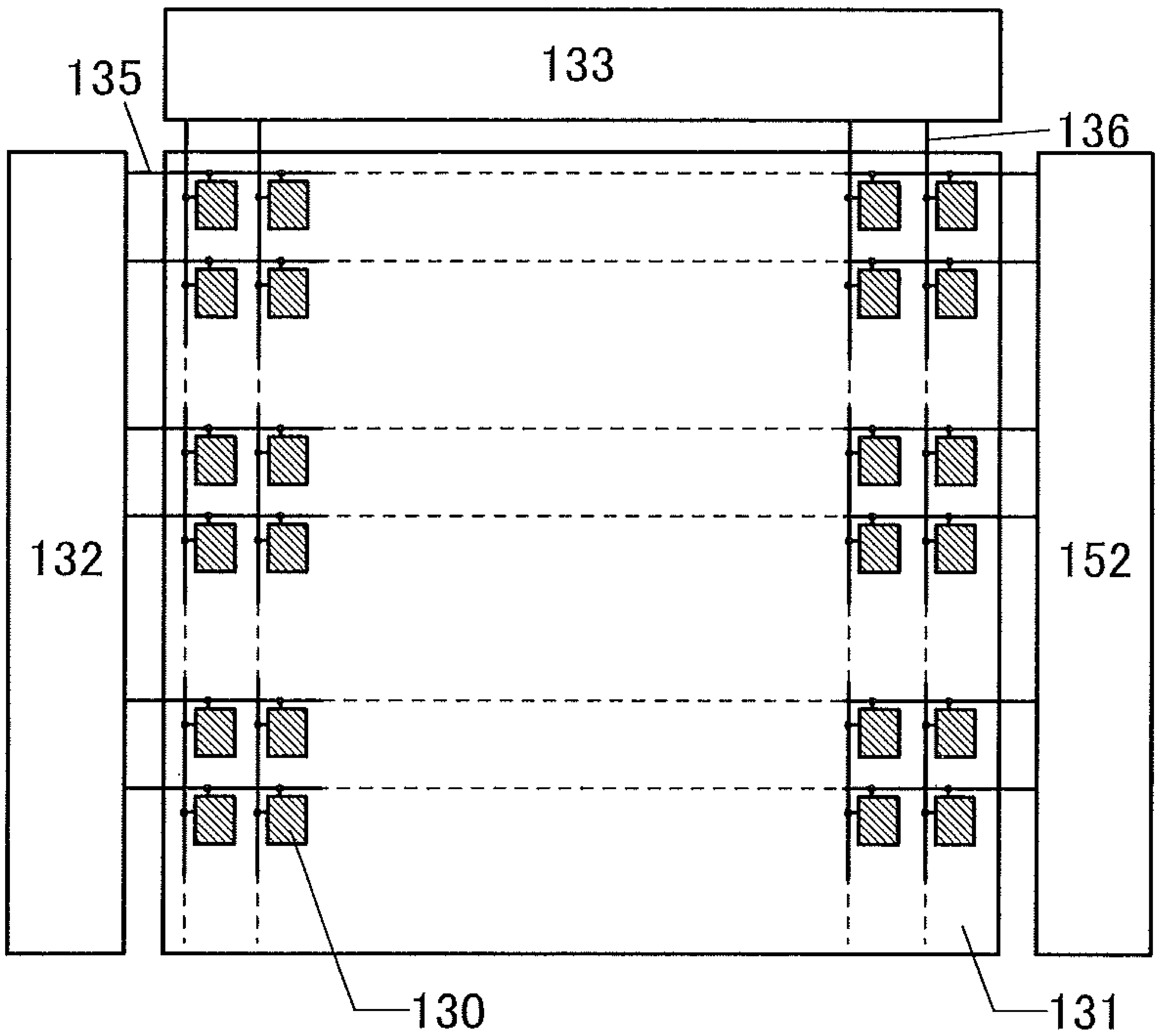


FIG. 5B

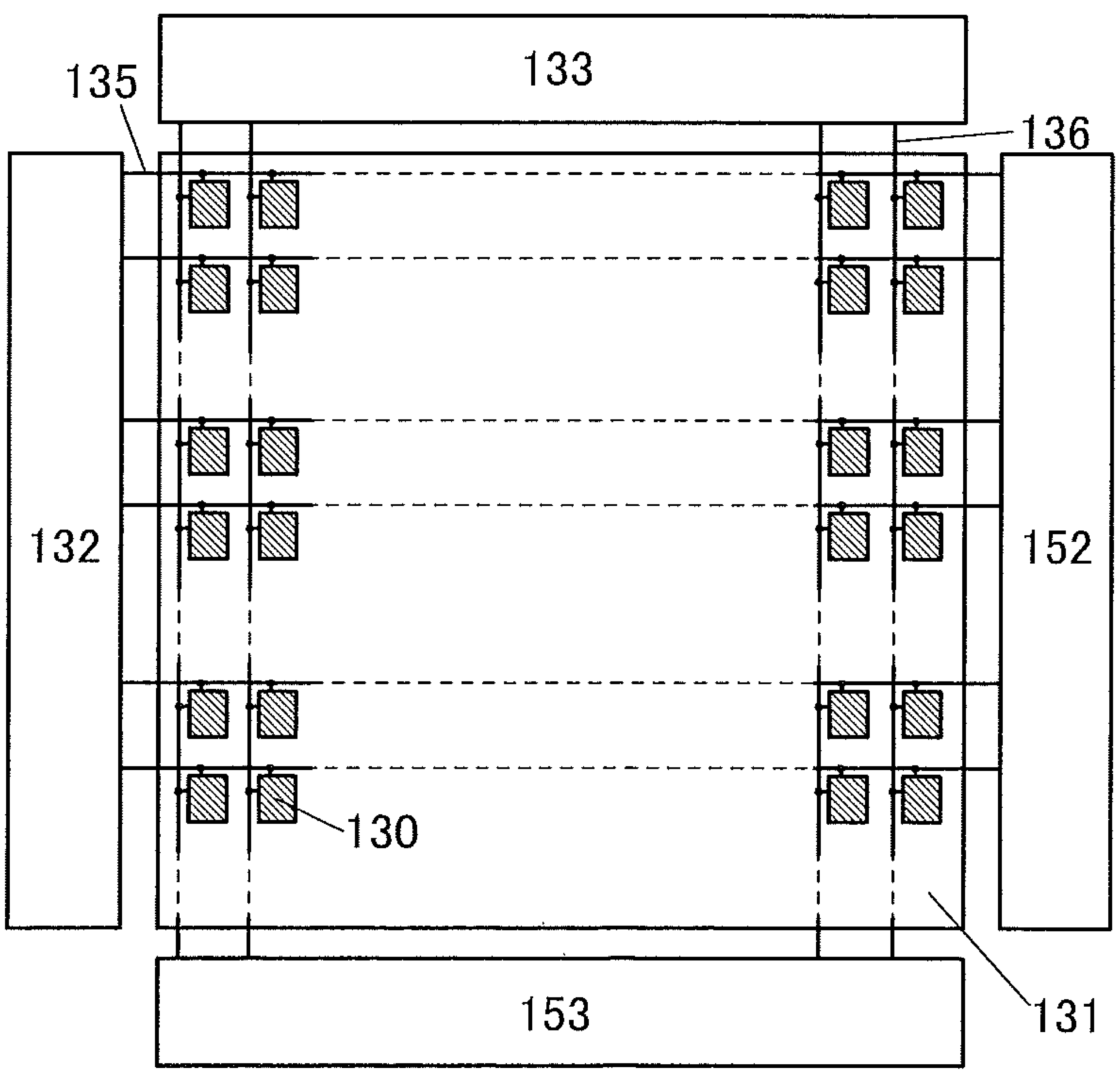


FIG. 6A

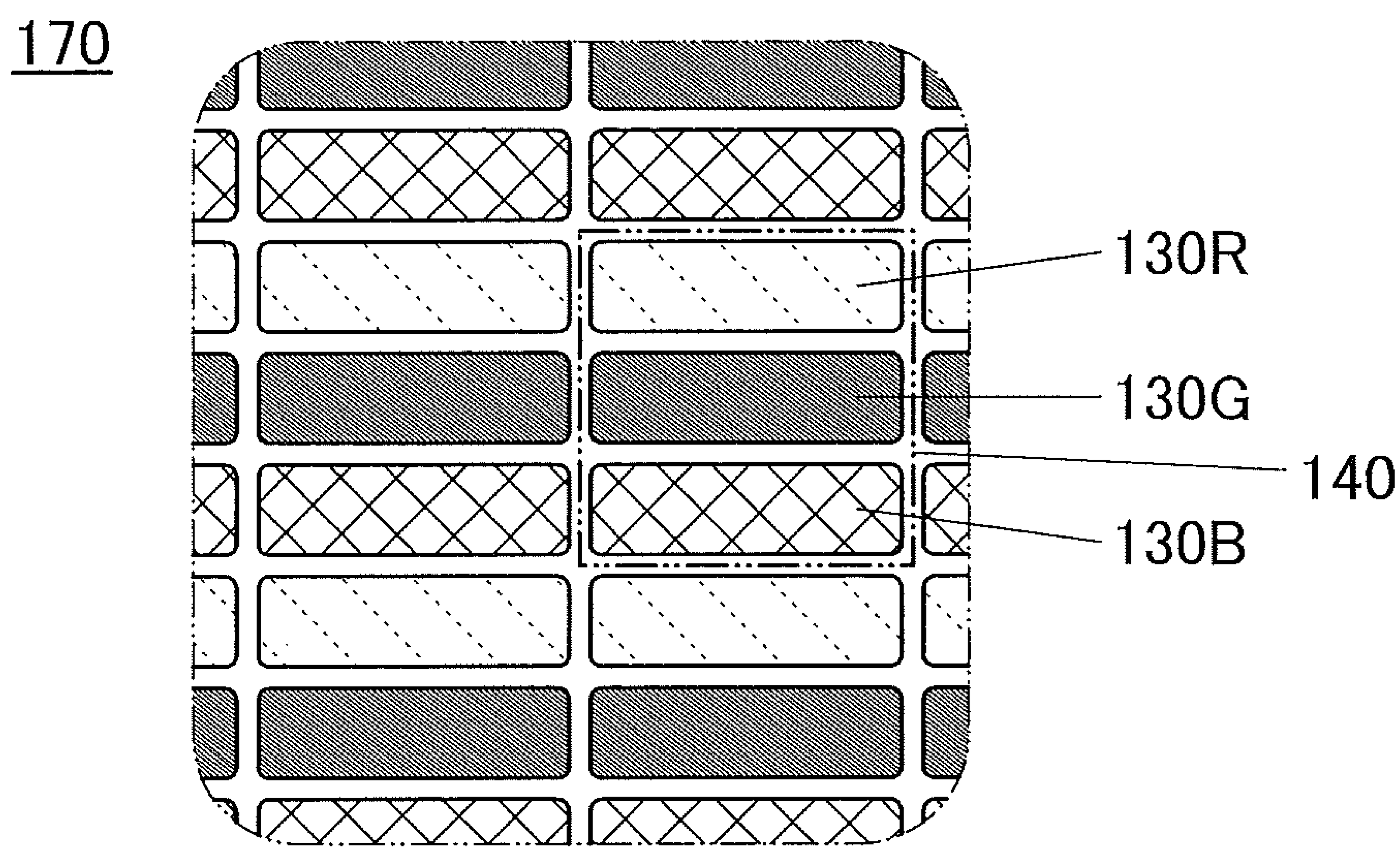


FIG. 6B

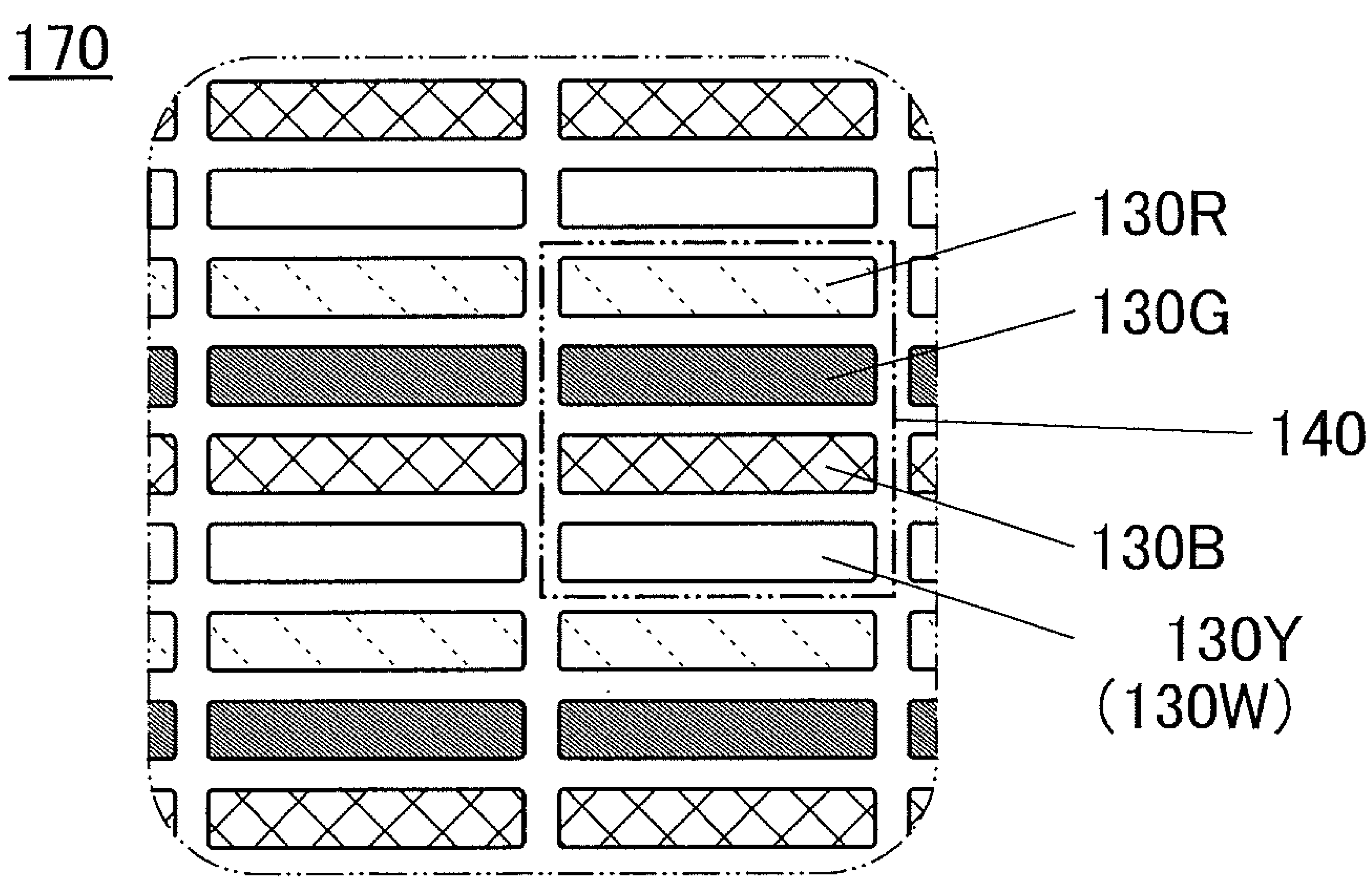


FIG. 7A

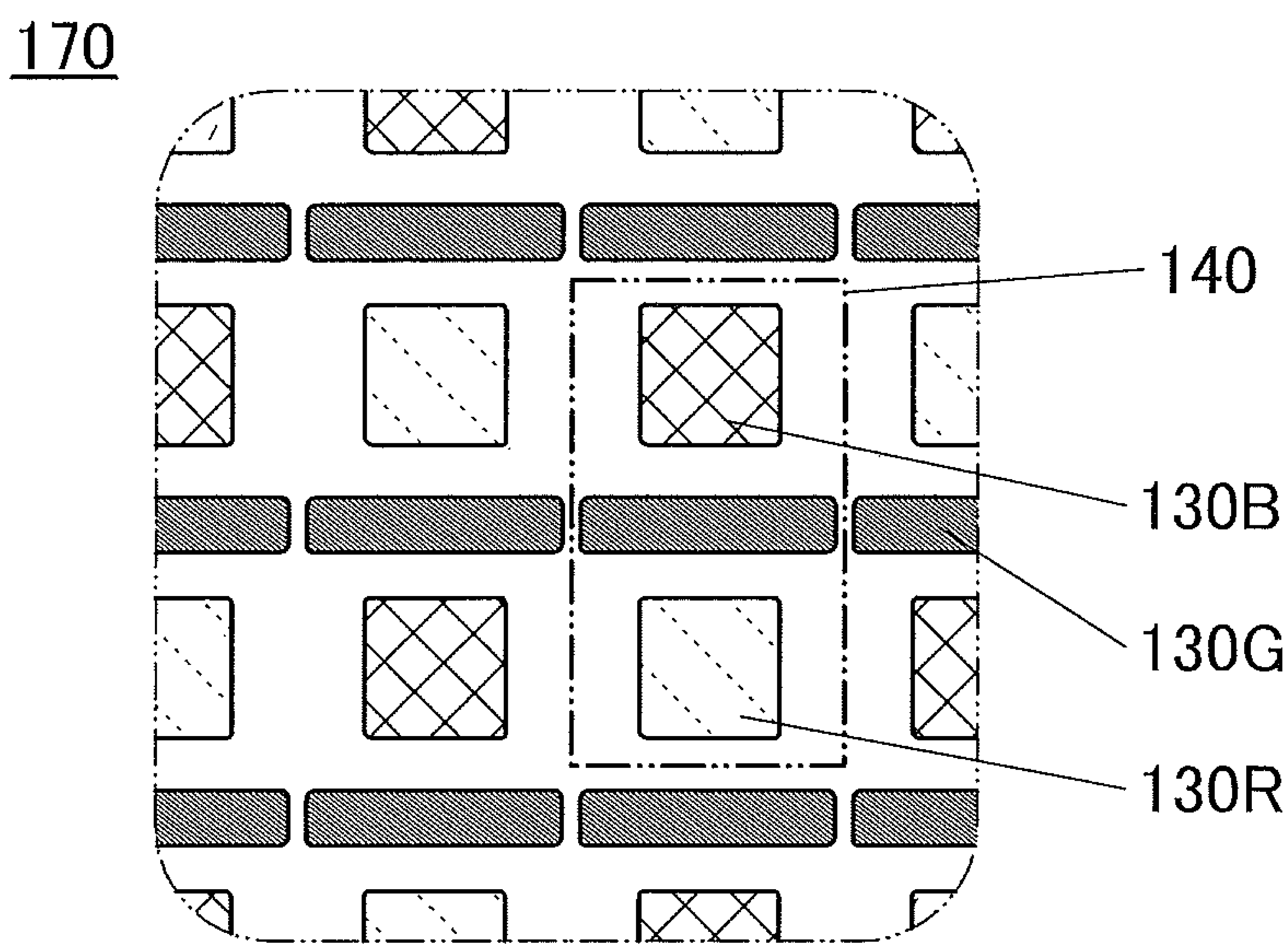


FIG. 7B

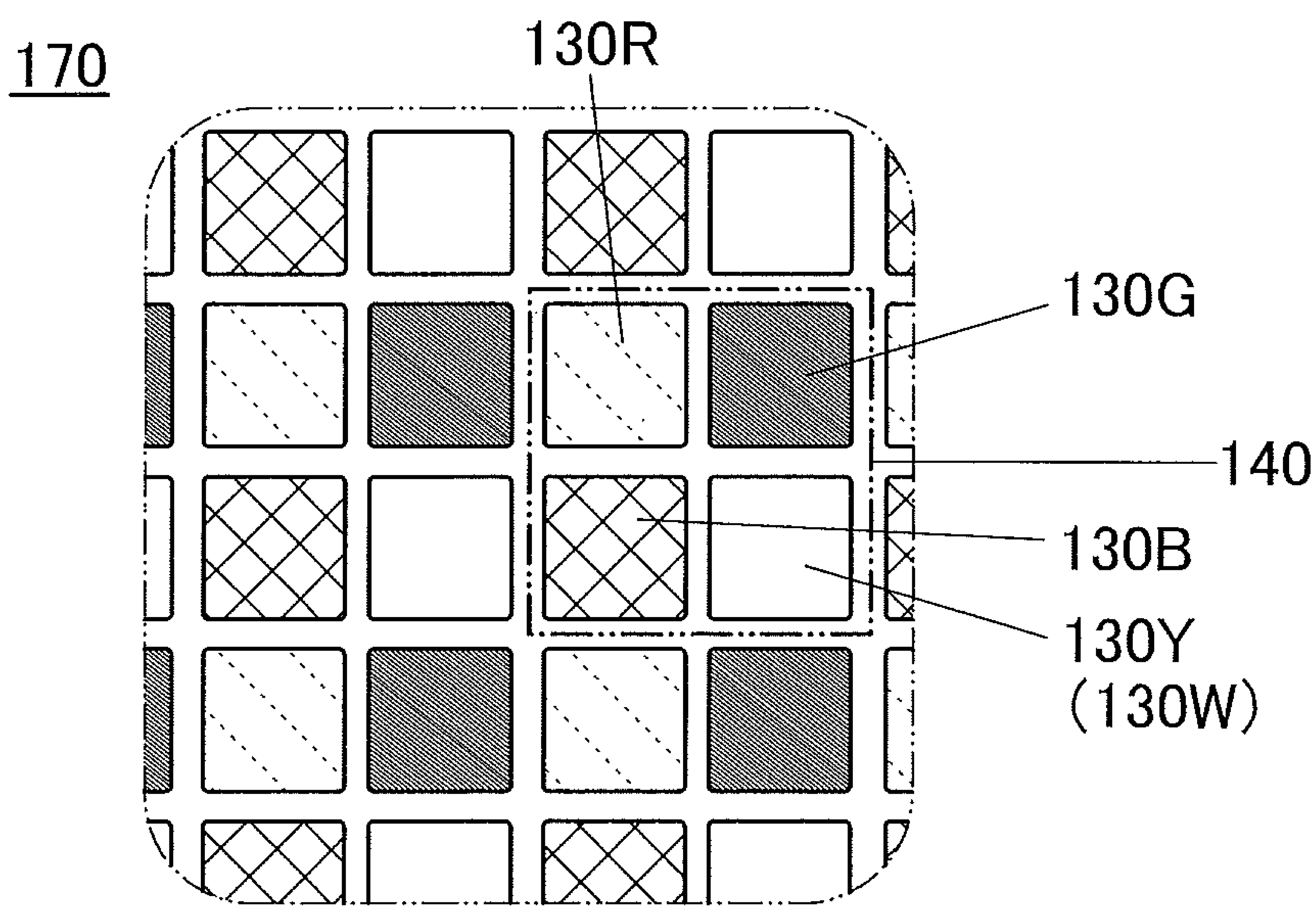


FIG. 8A

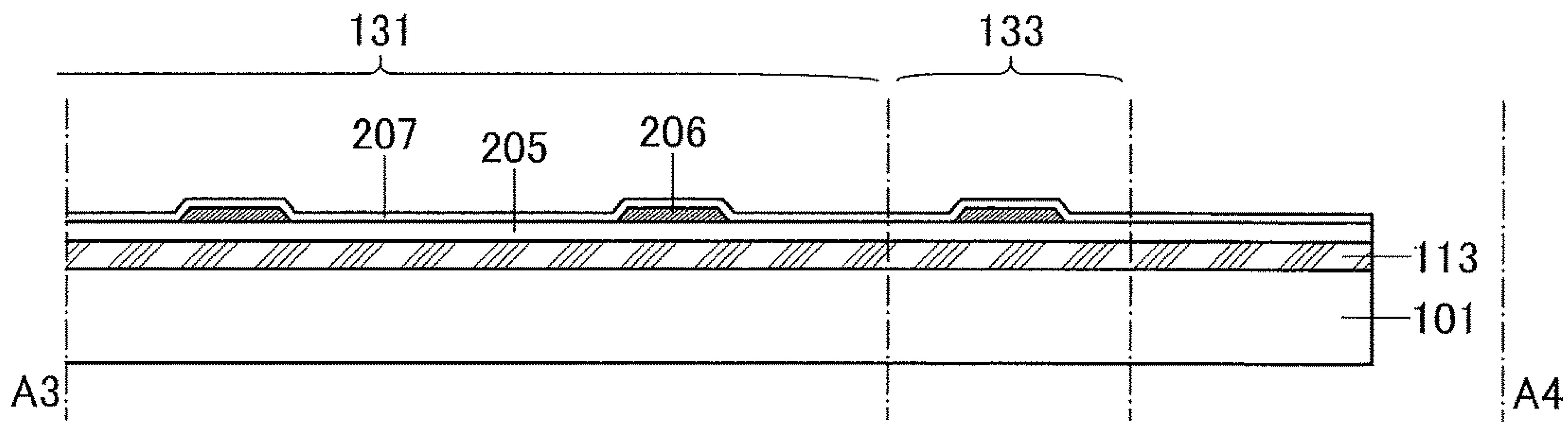


FIG. 8B

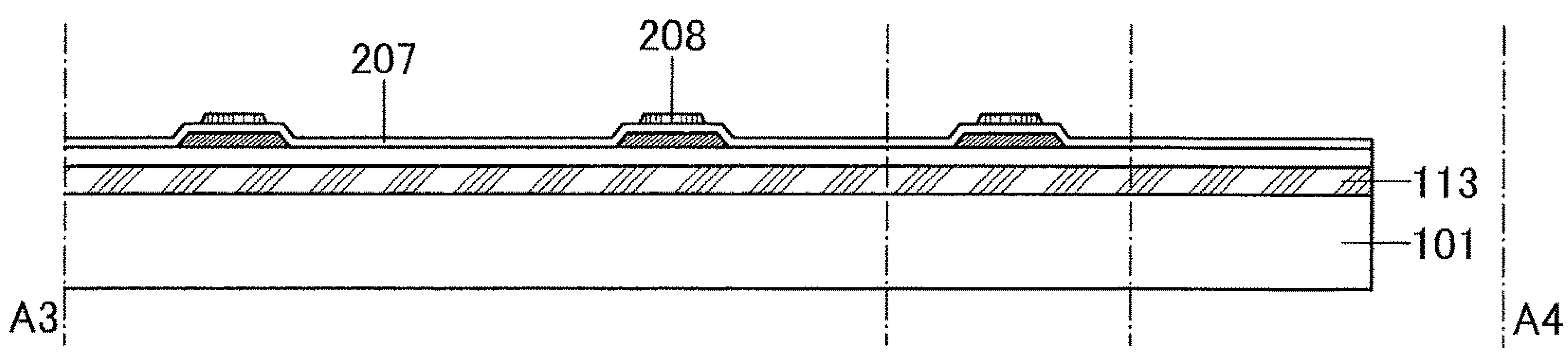


FIG. 8C

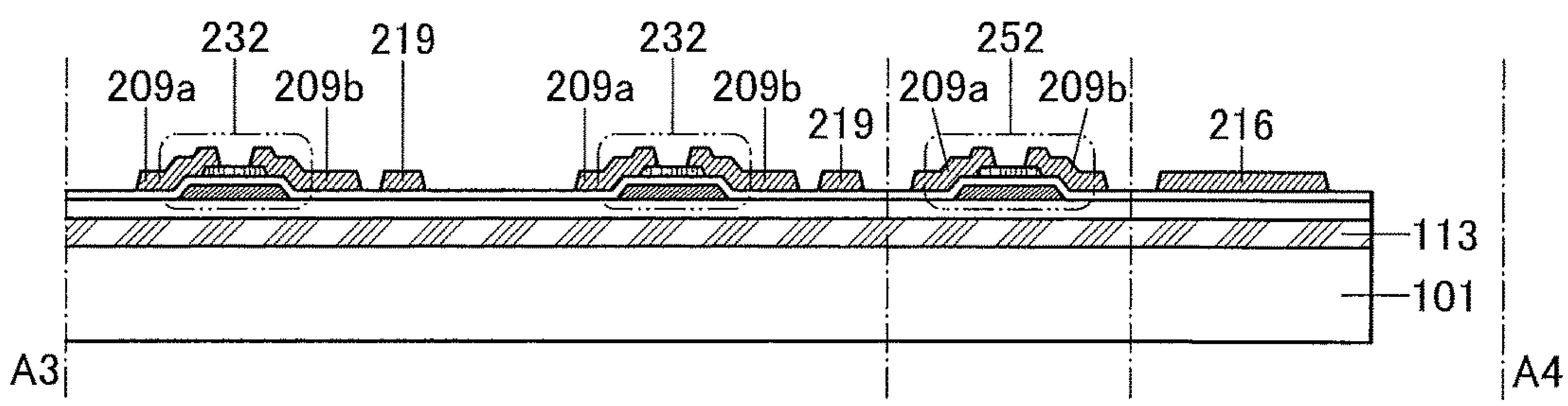


FIG. 8D

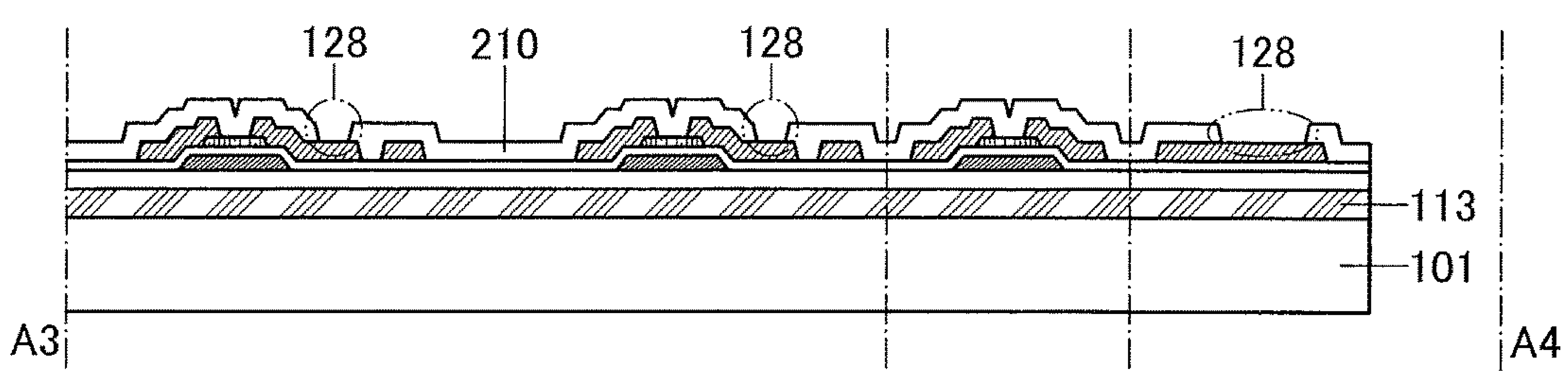


FIG. 9A

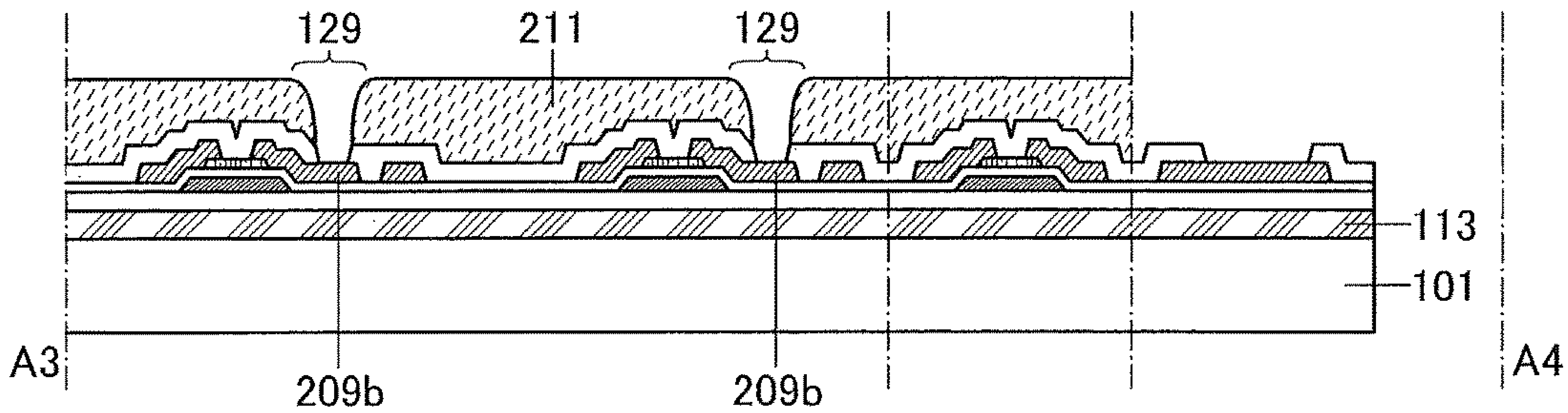


FIG. 9B

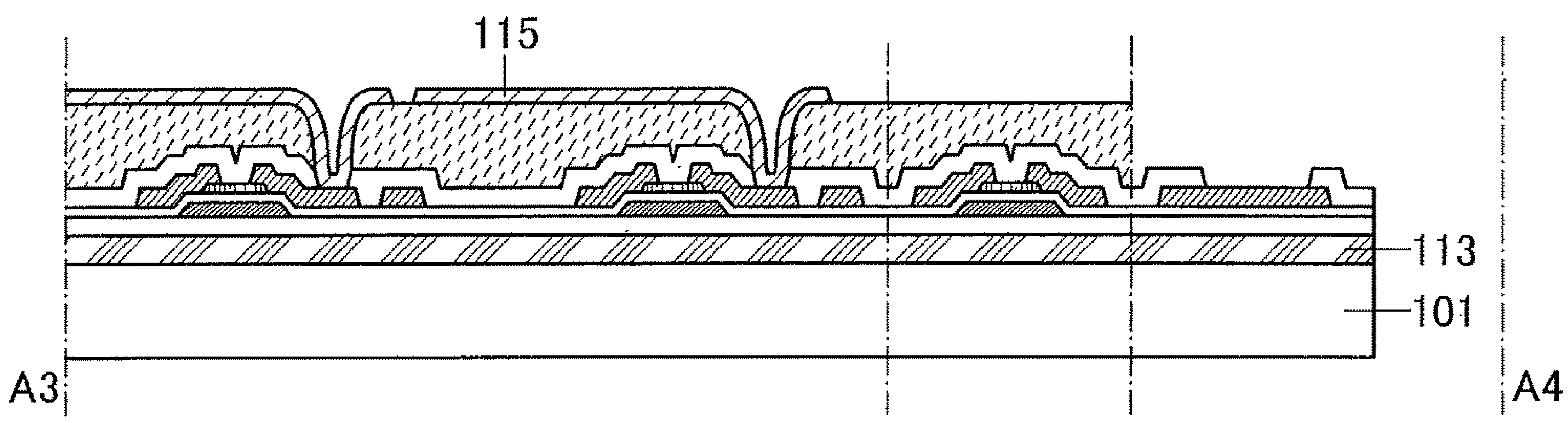


FIG. 9C

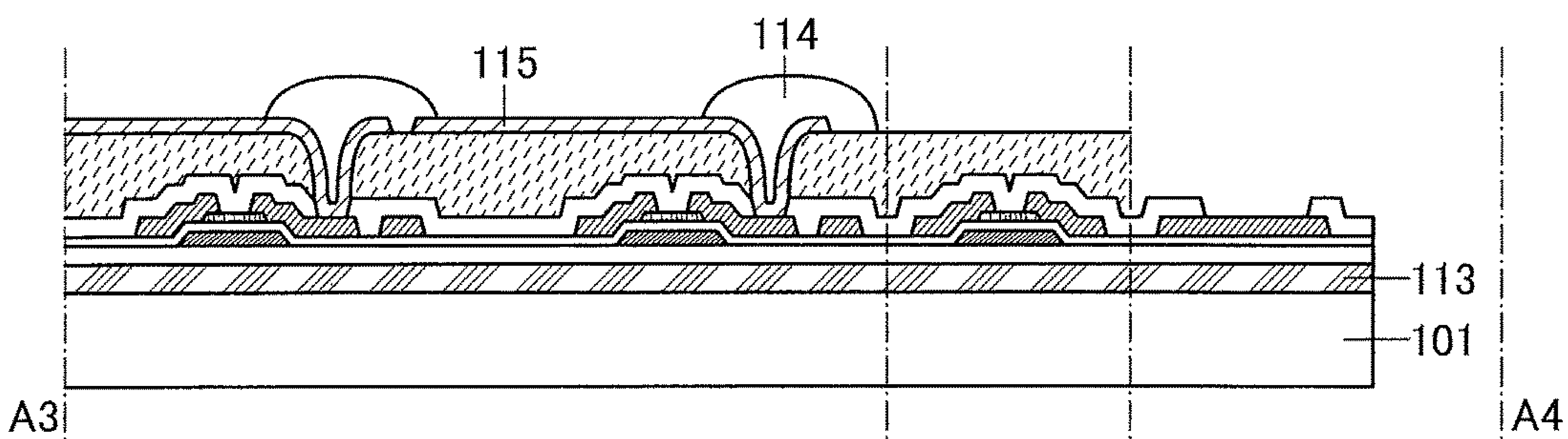
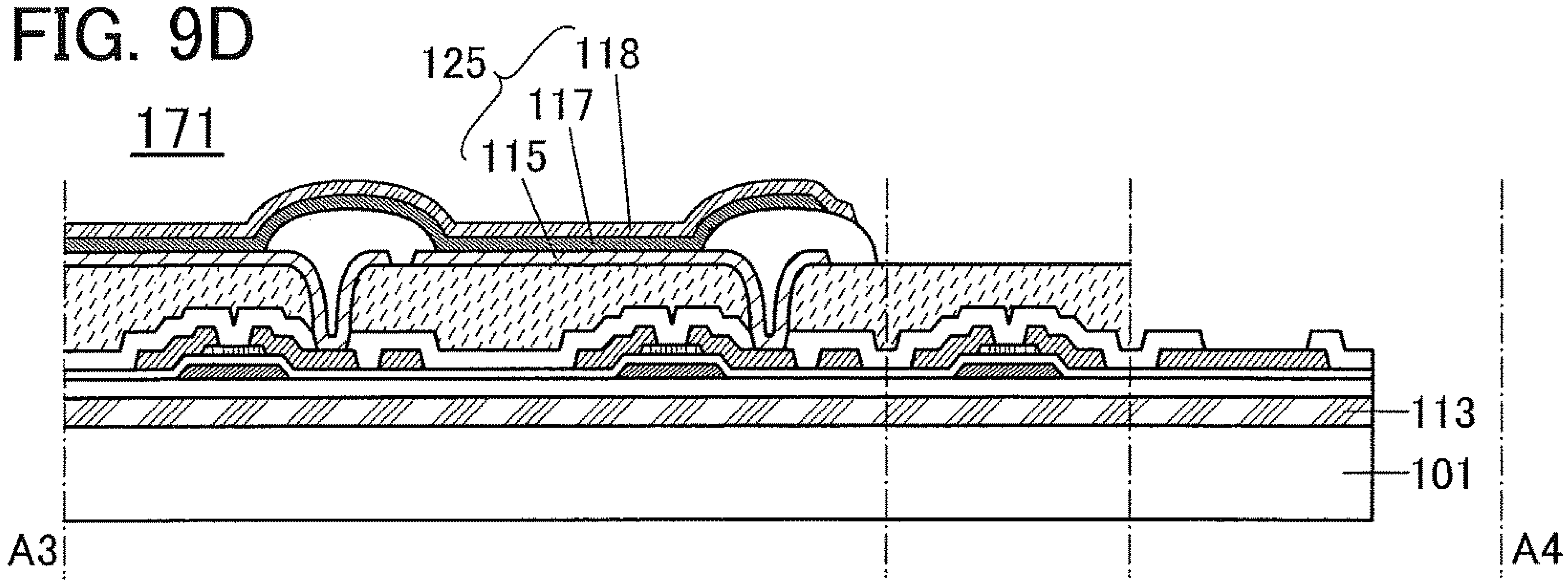


FIG. 9D



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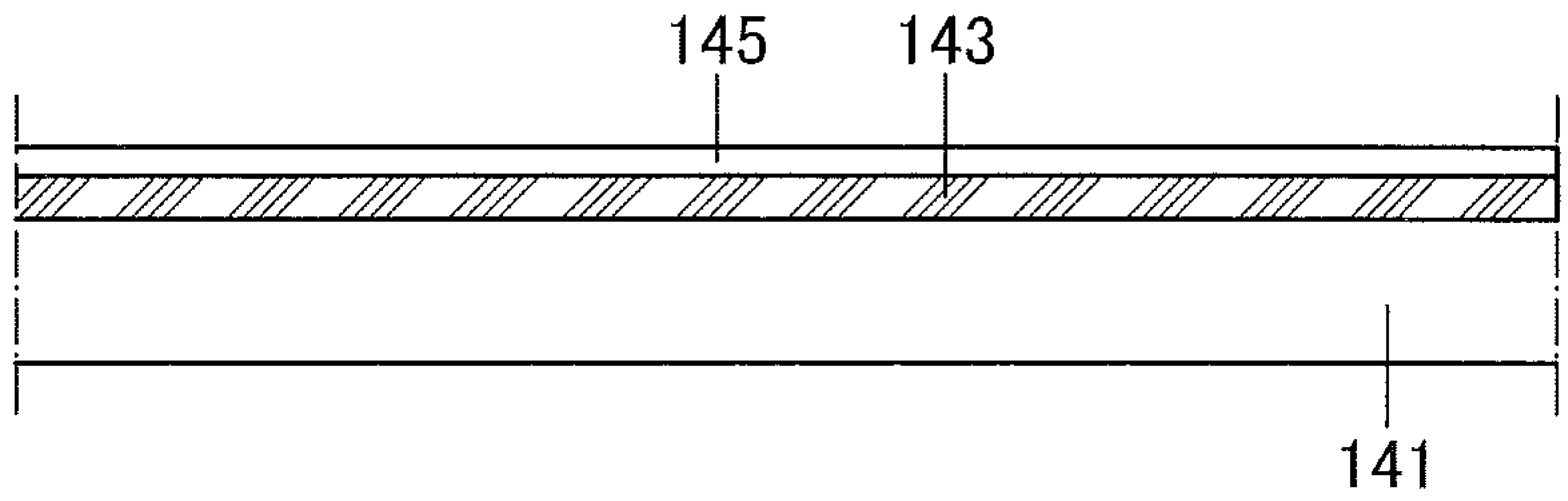
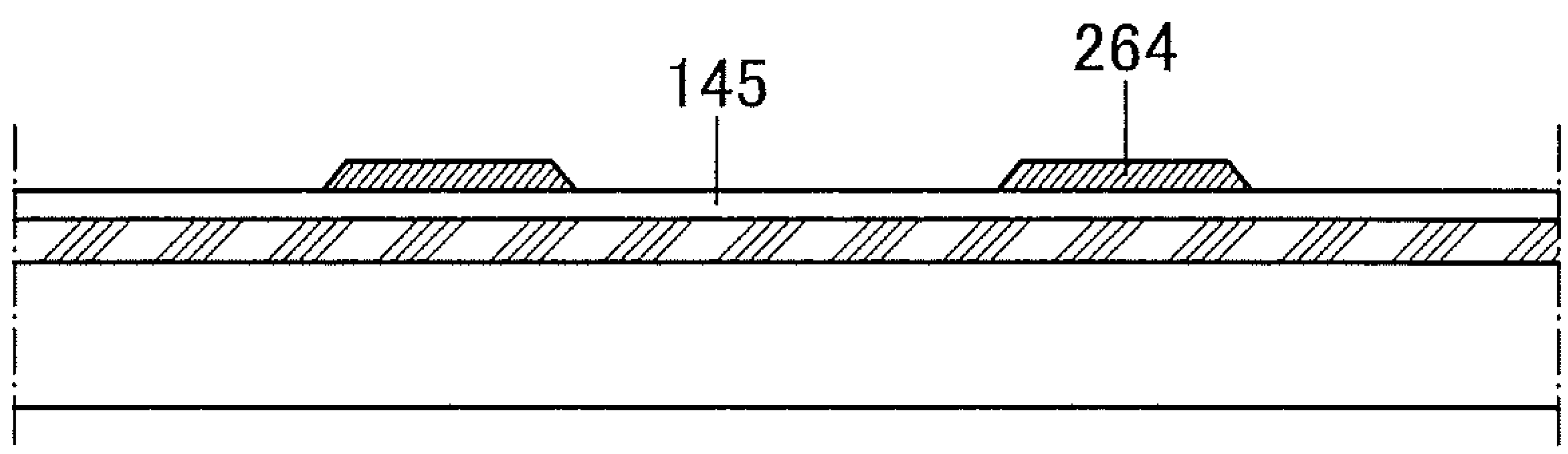


FIG. 10B



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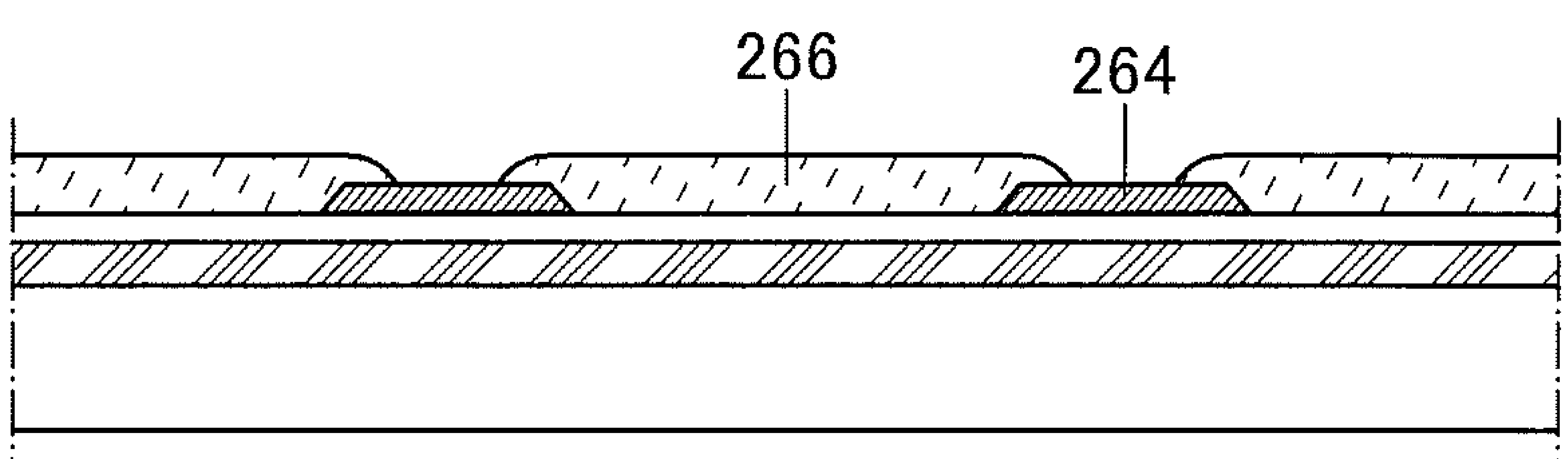
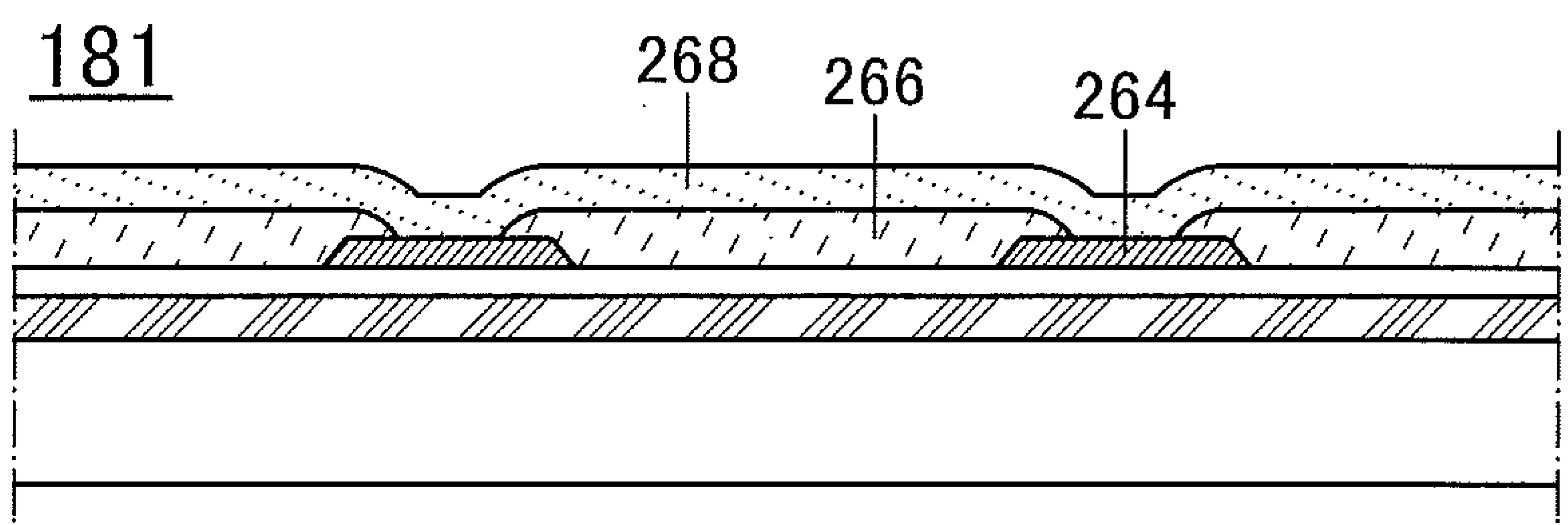


FIG. 10D



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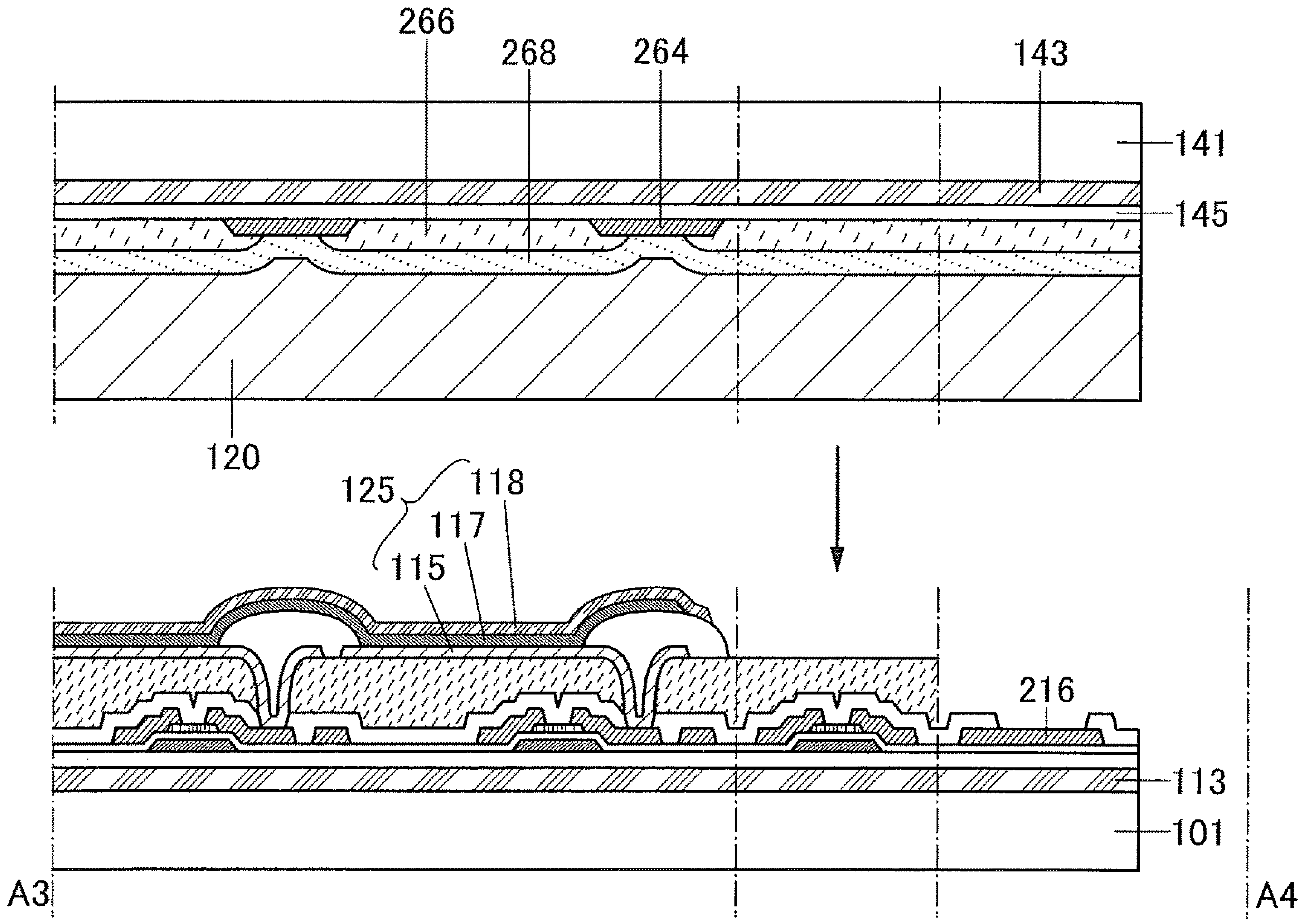
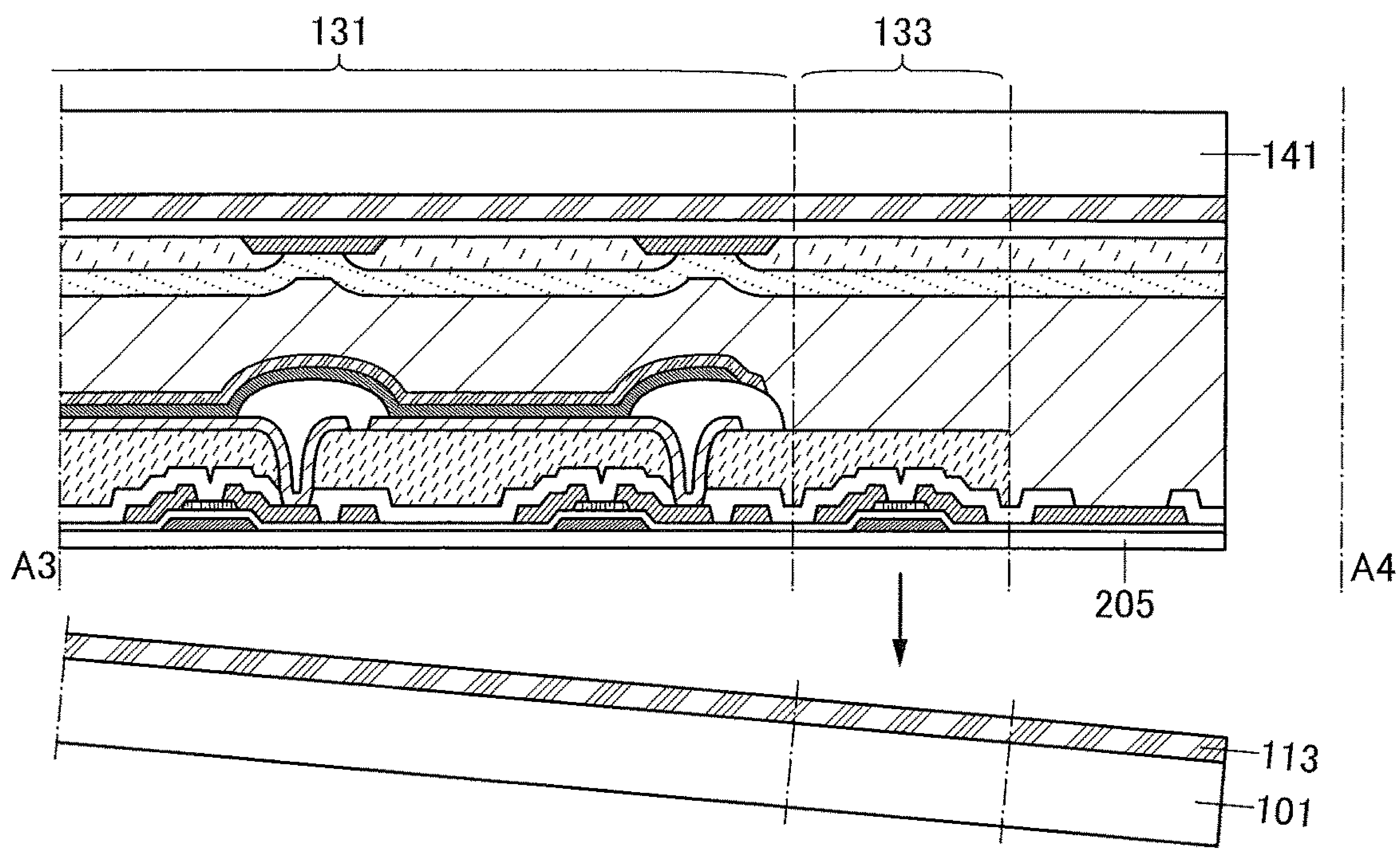


FIG. 11B



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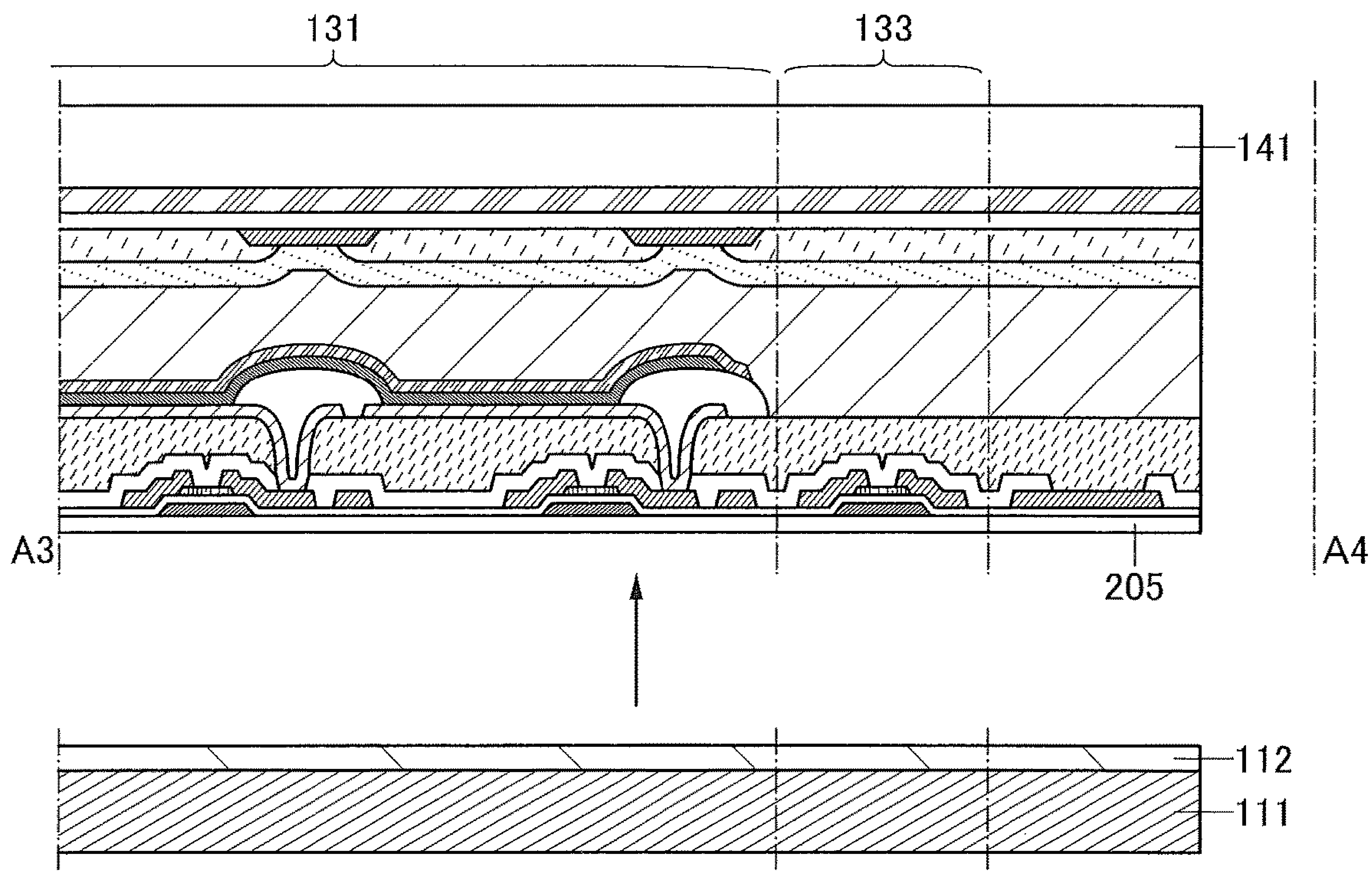

FIG. 12B

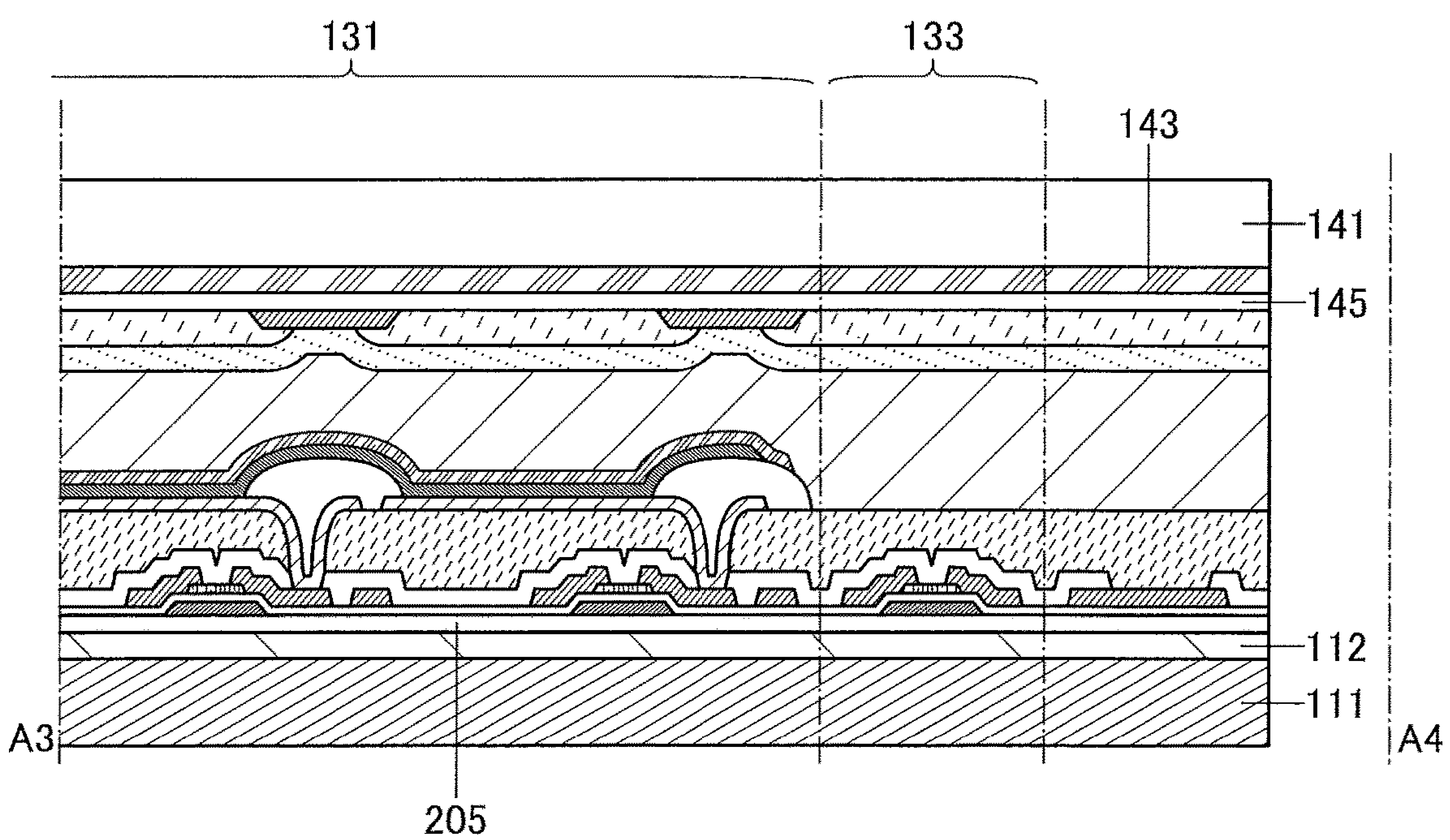

FIG. 13A

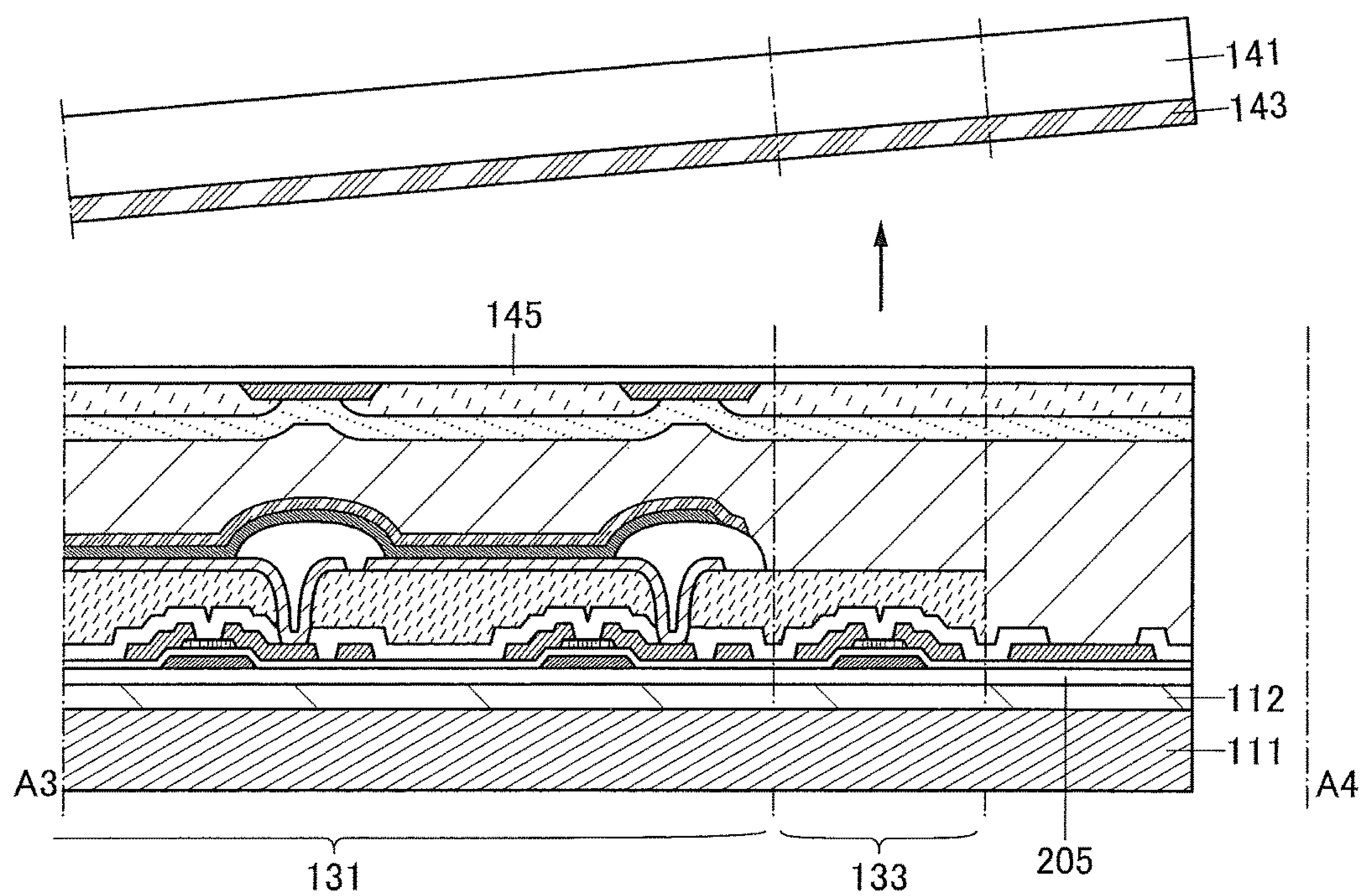

FIG. 13B

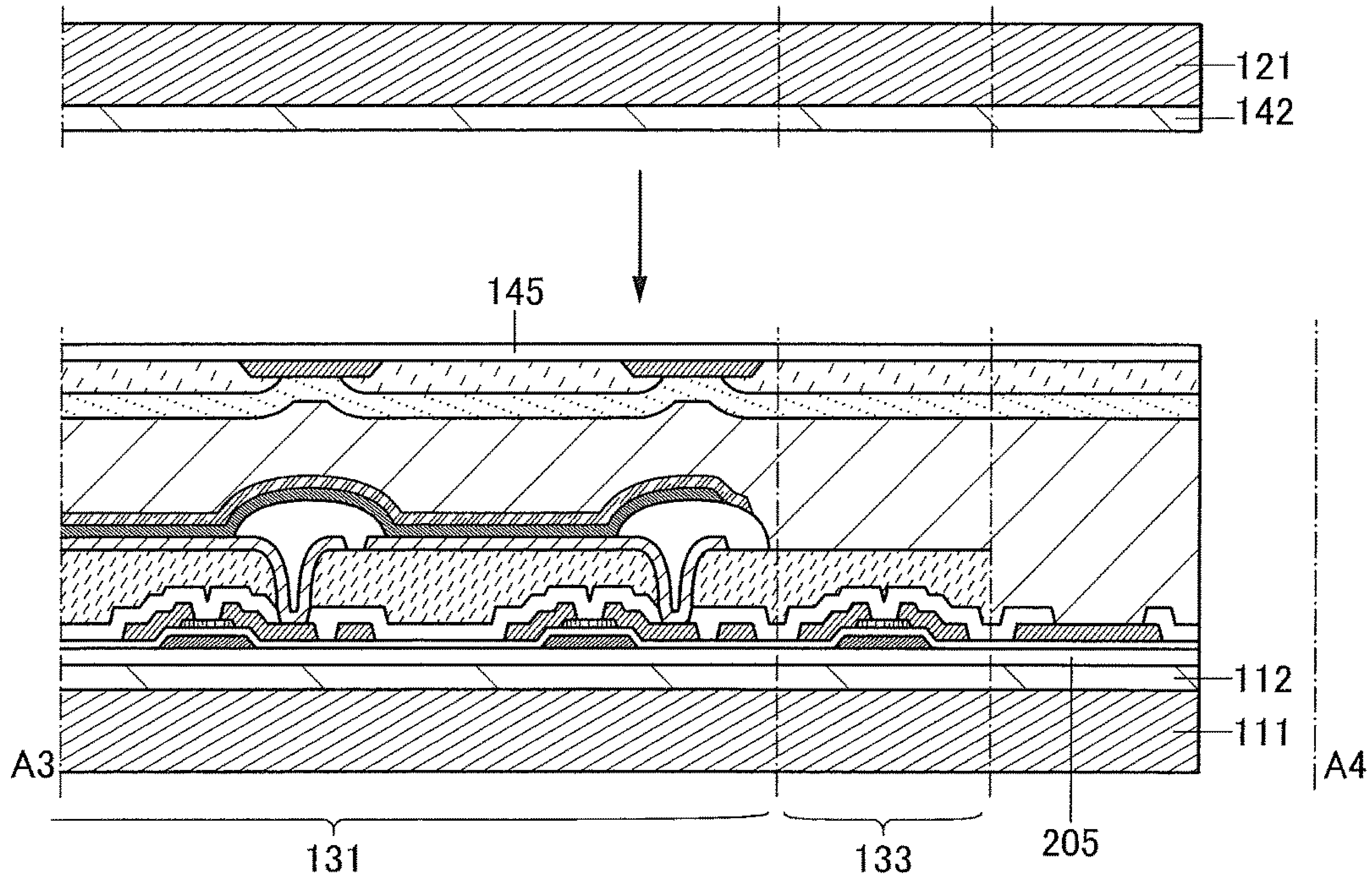

FIG. 14A

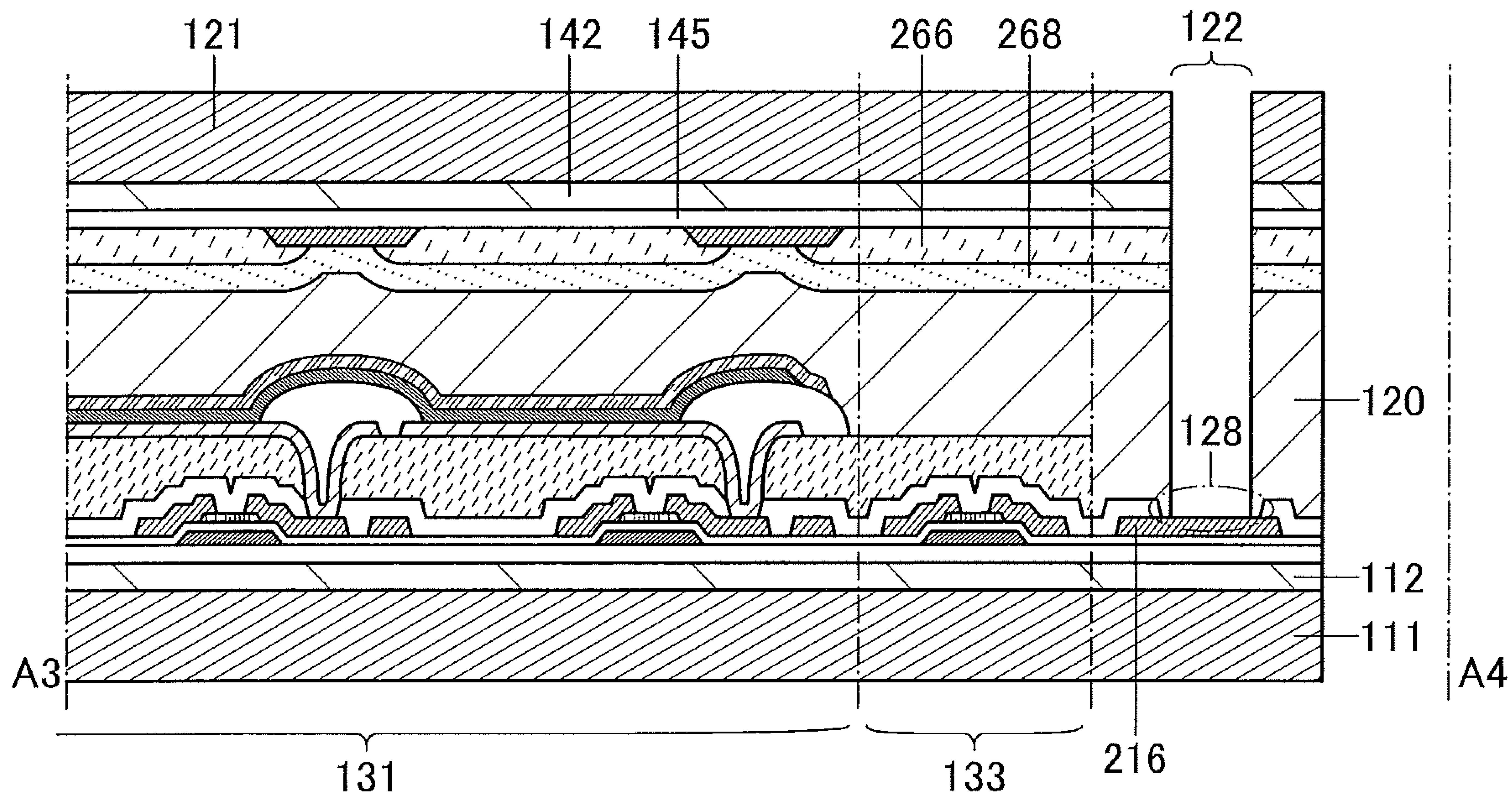

FIG. 14B

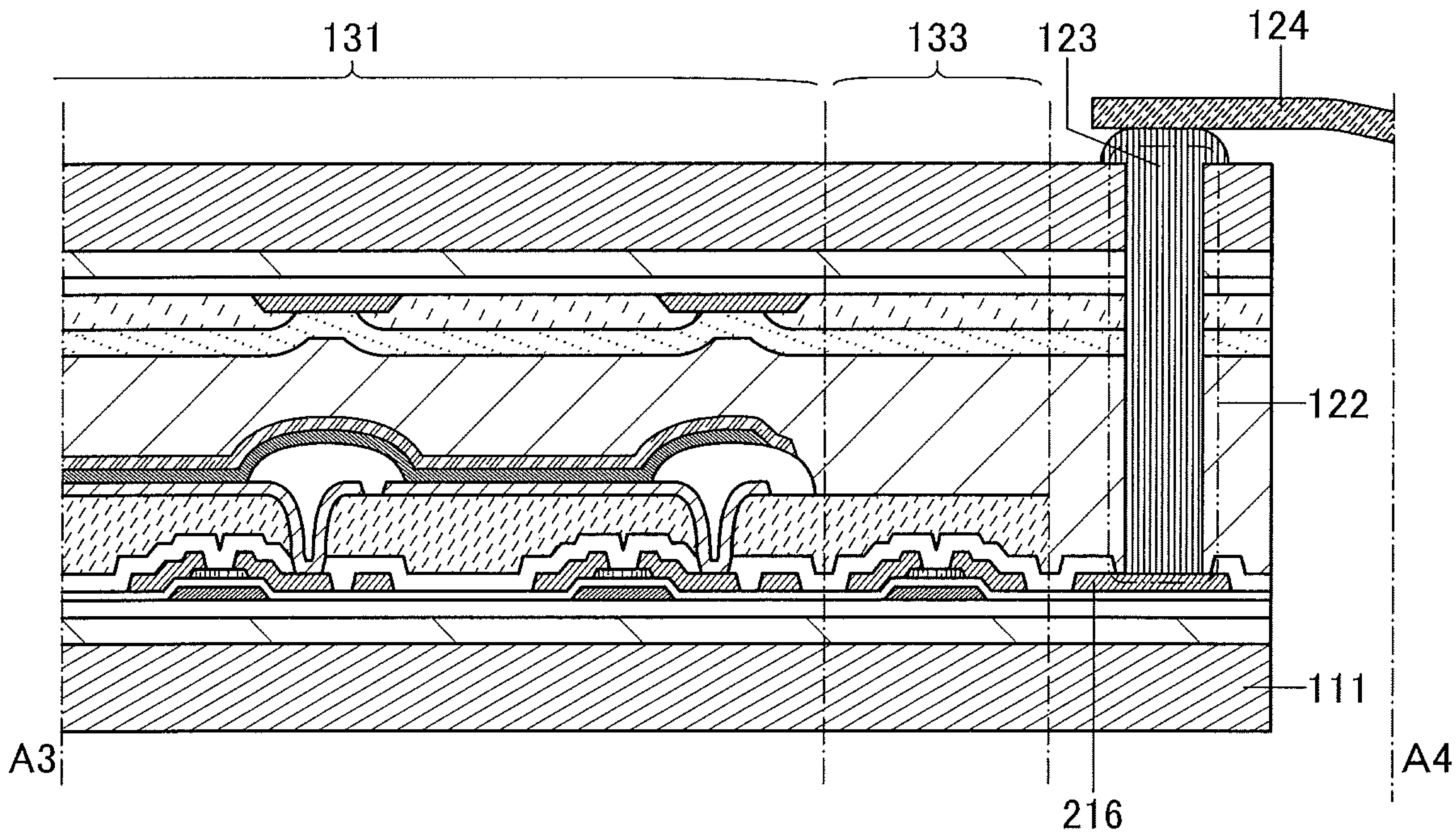

FIG. 15A

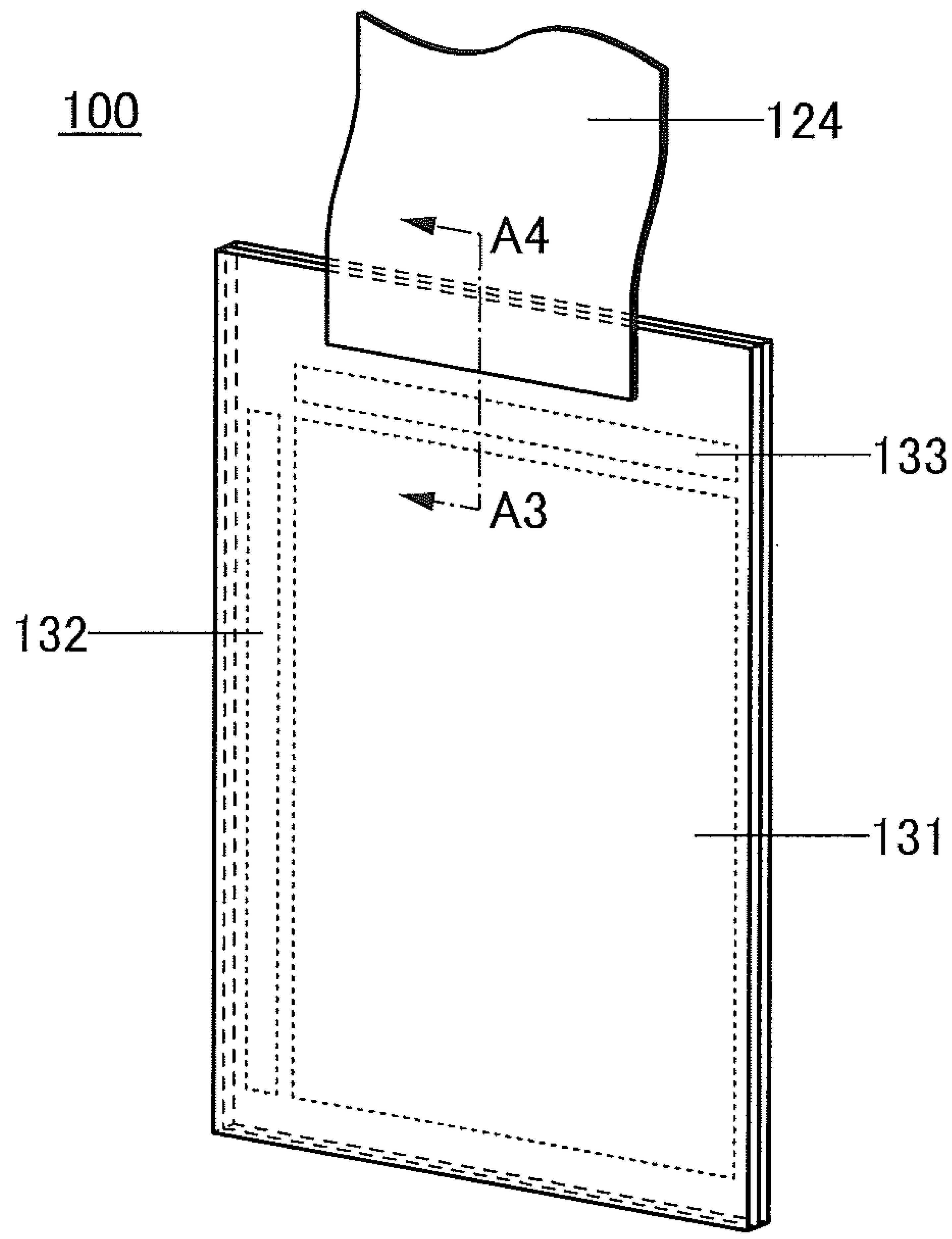

FIG. 15B

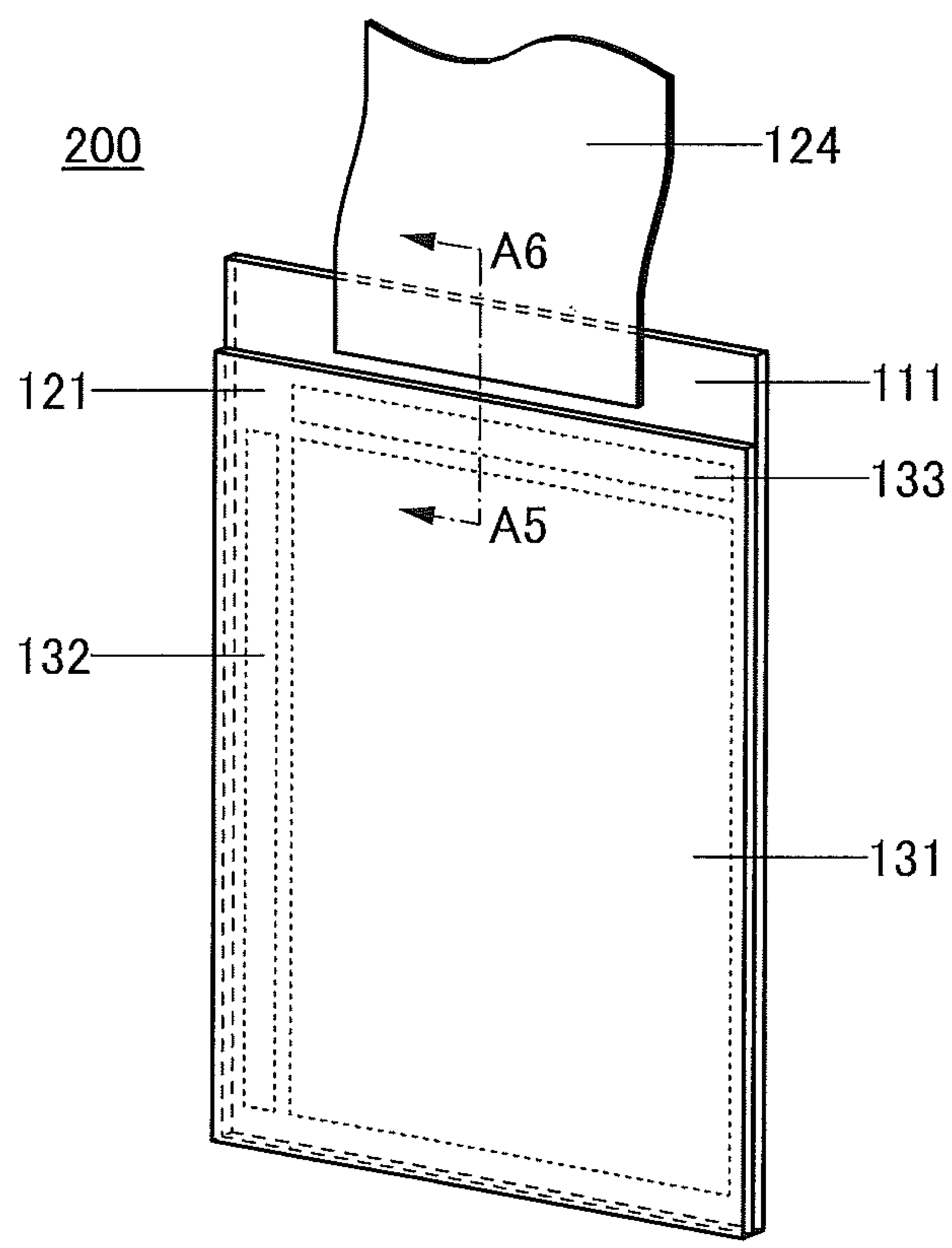

FIG. 16A

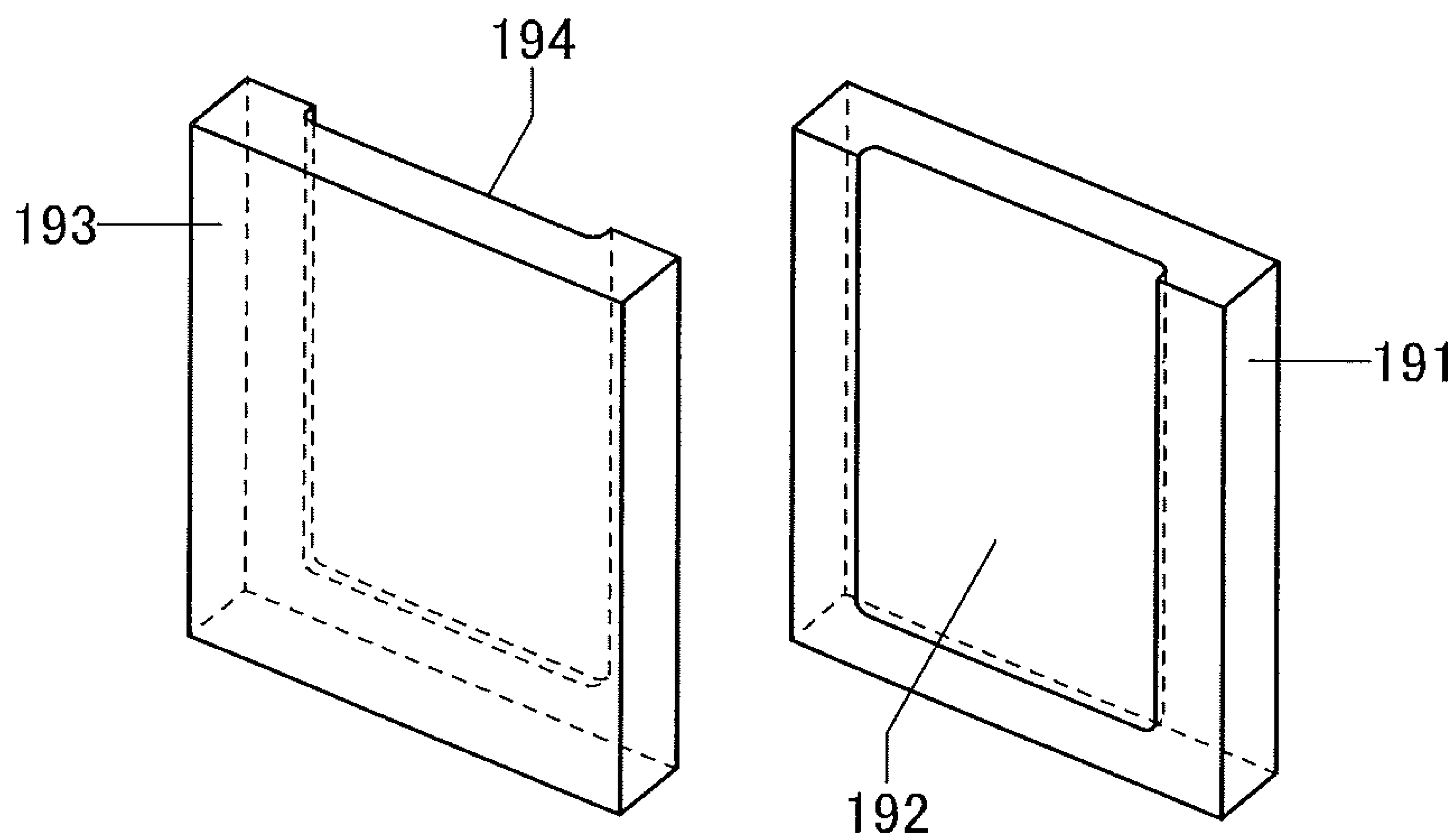

FIG. 16B

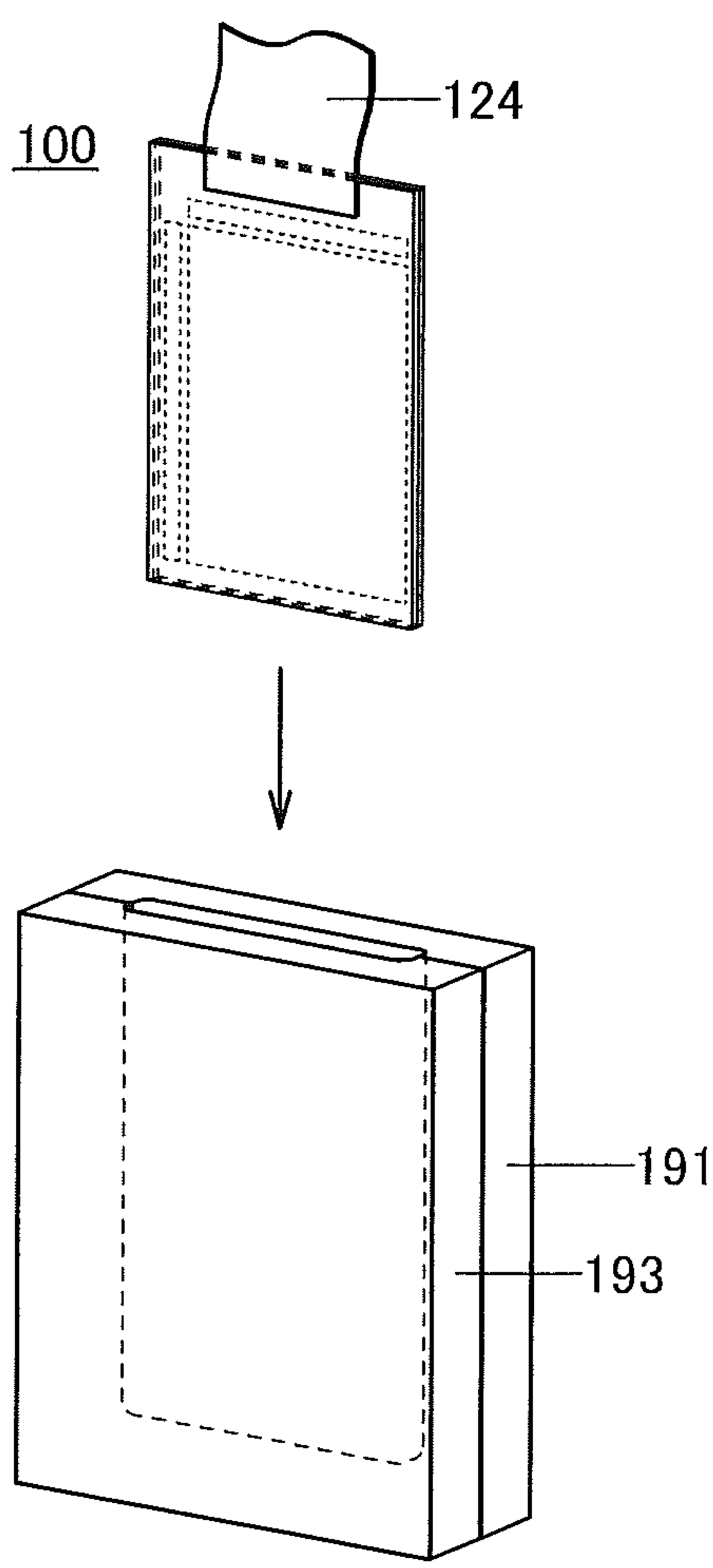

FIG. 16C

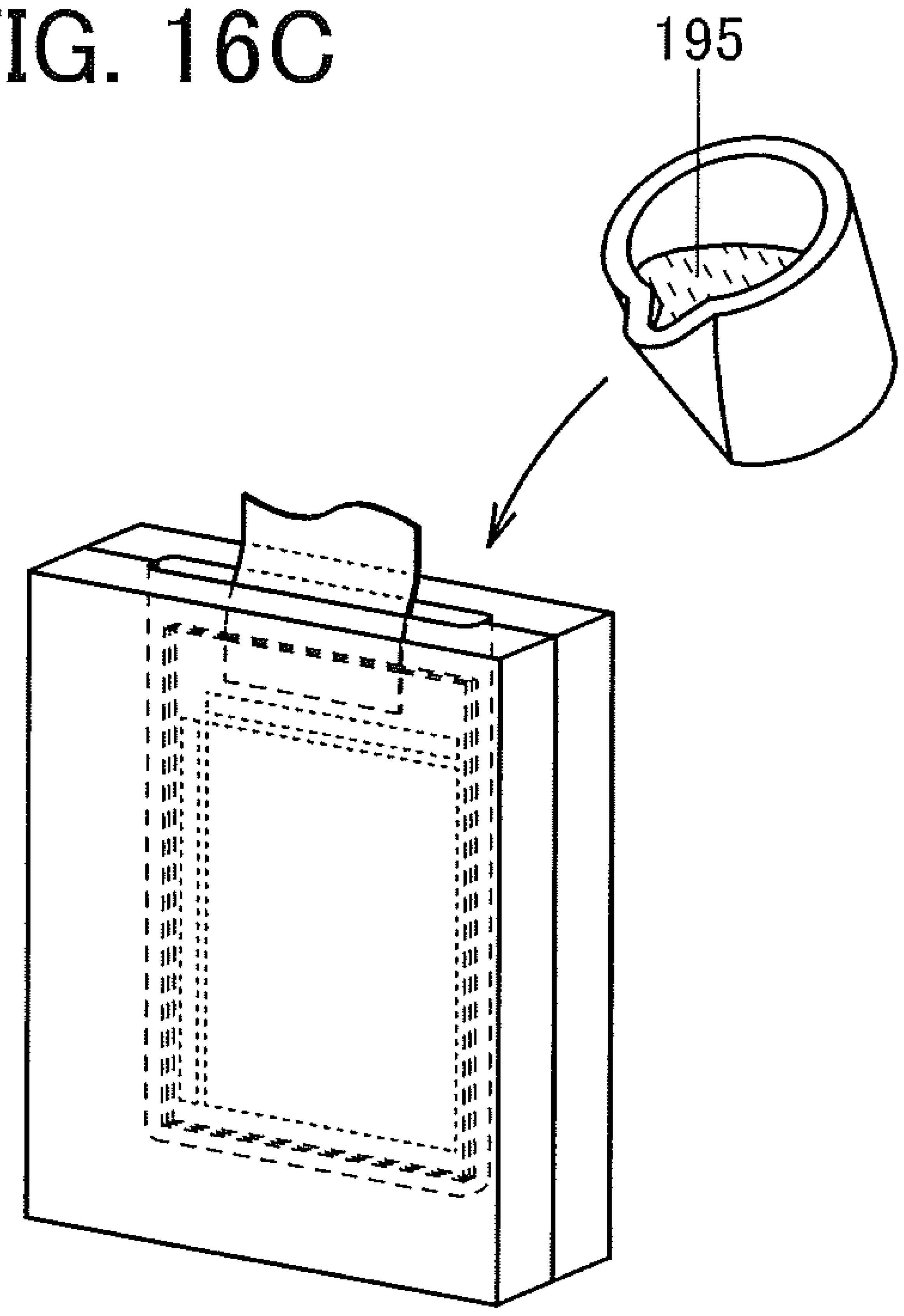

FIG. 17

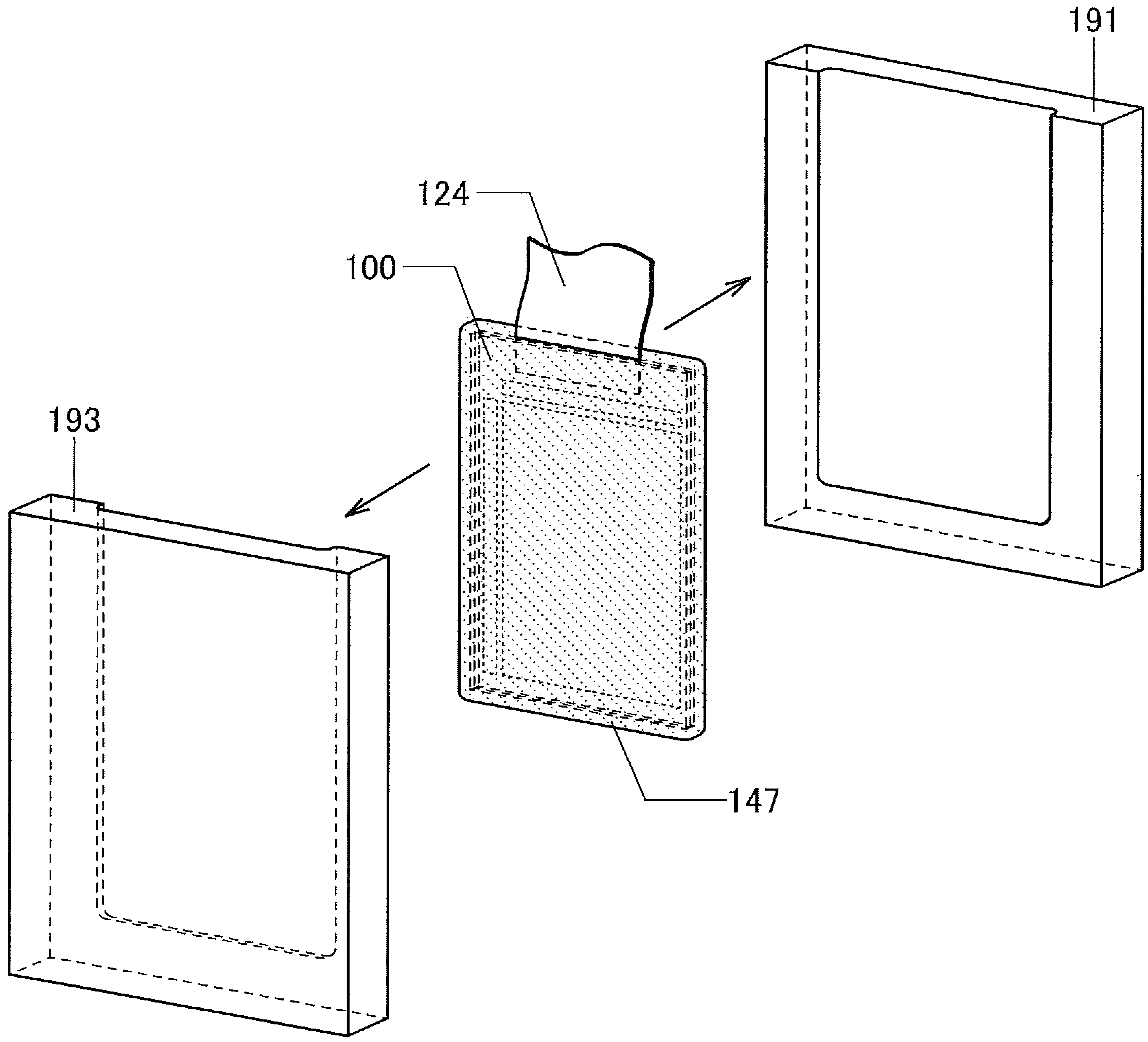

FIG. 18A1

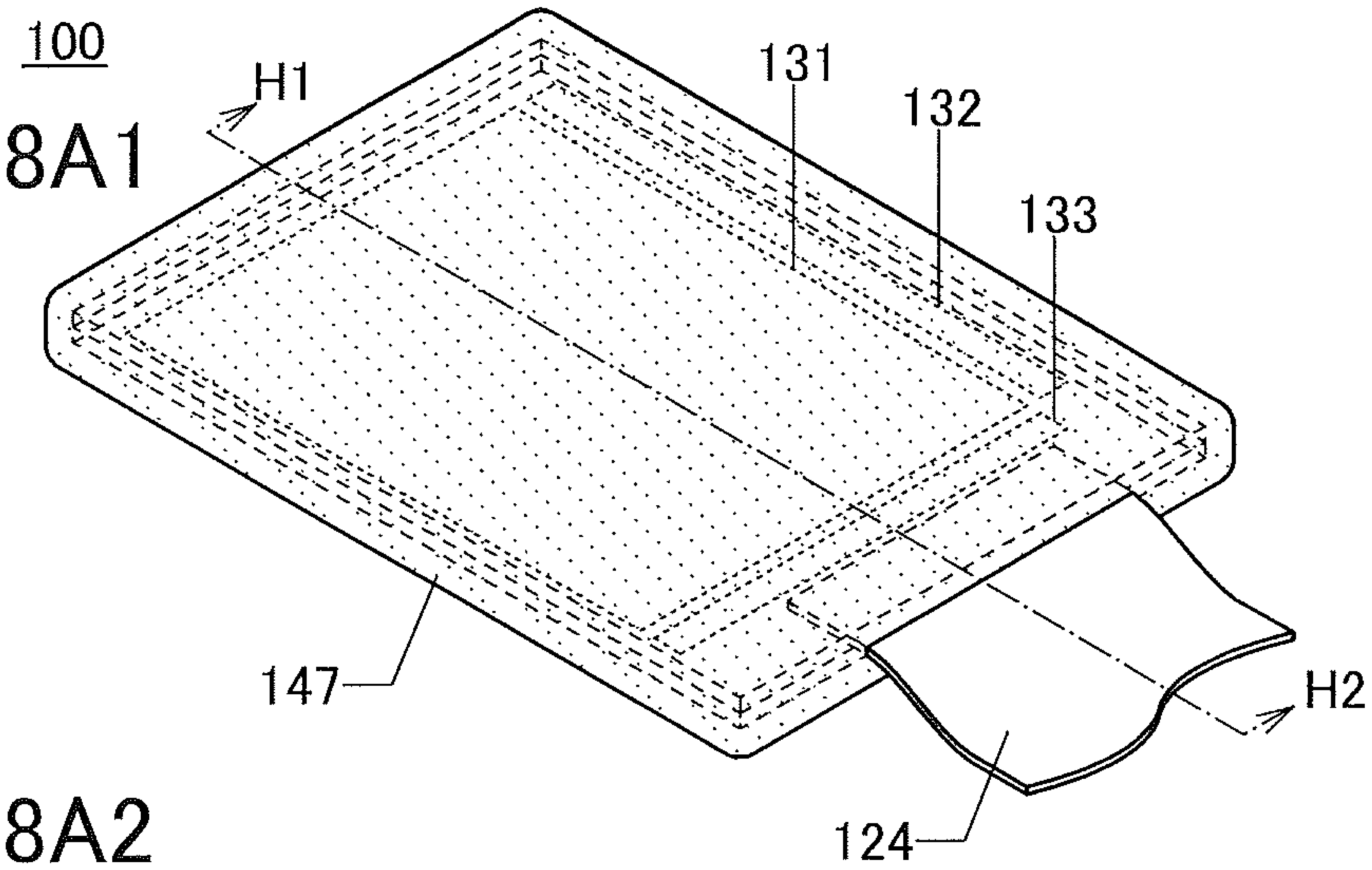

FIG. 18A2

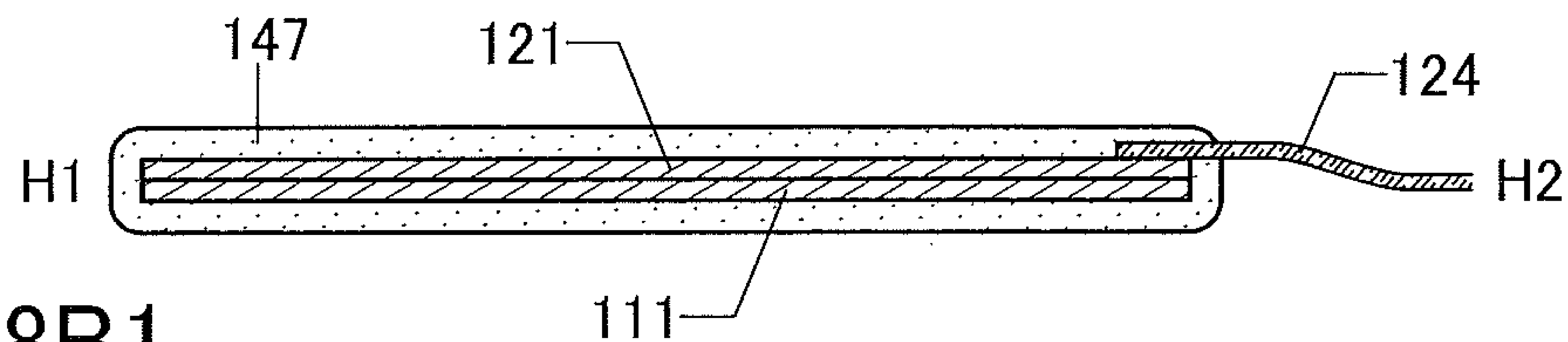

FIG. 18B1

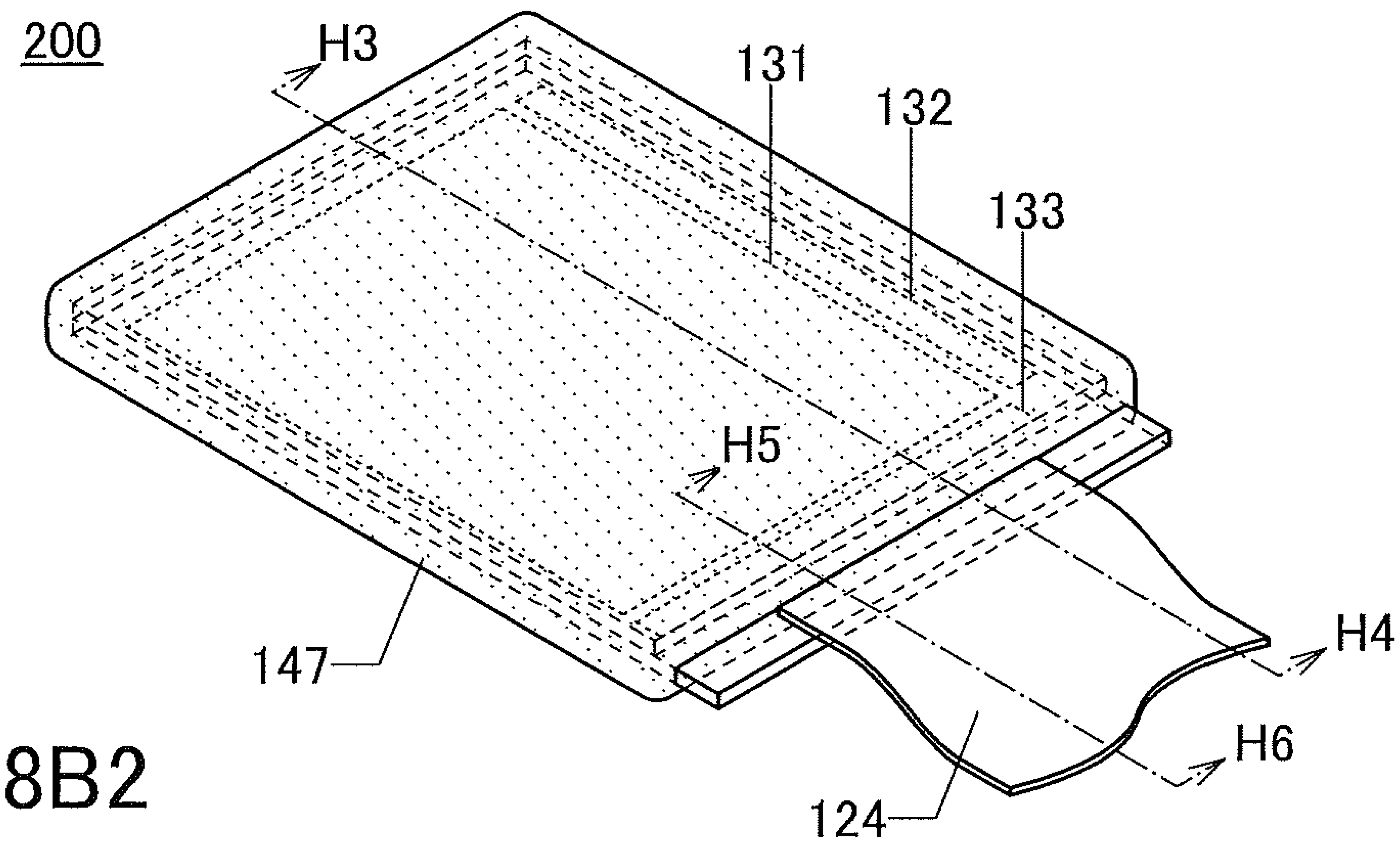

FIG. 18B2

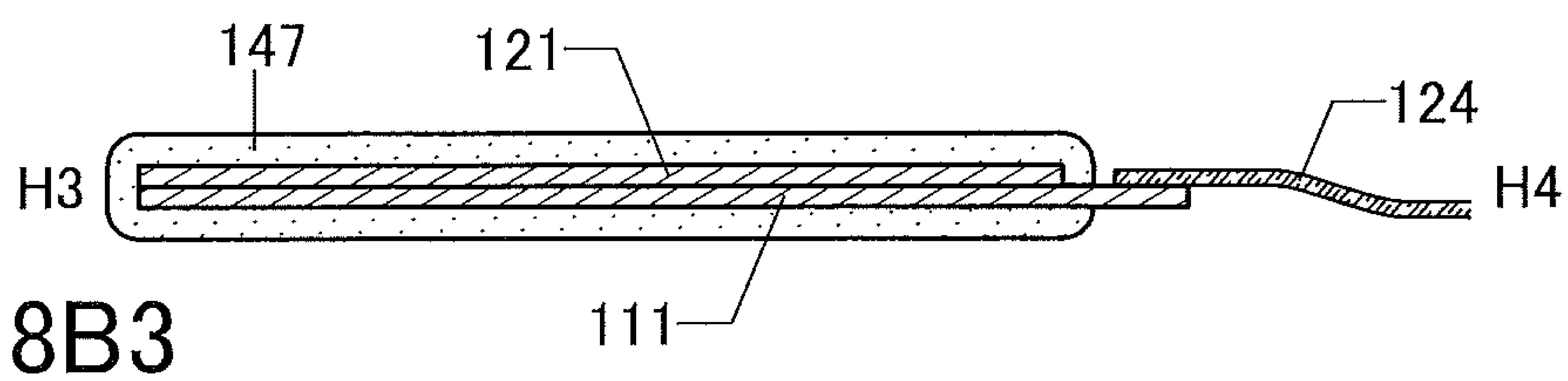

FIG. 18B3

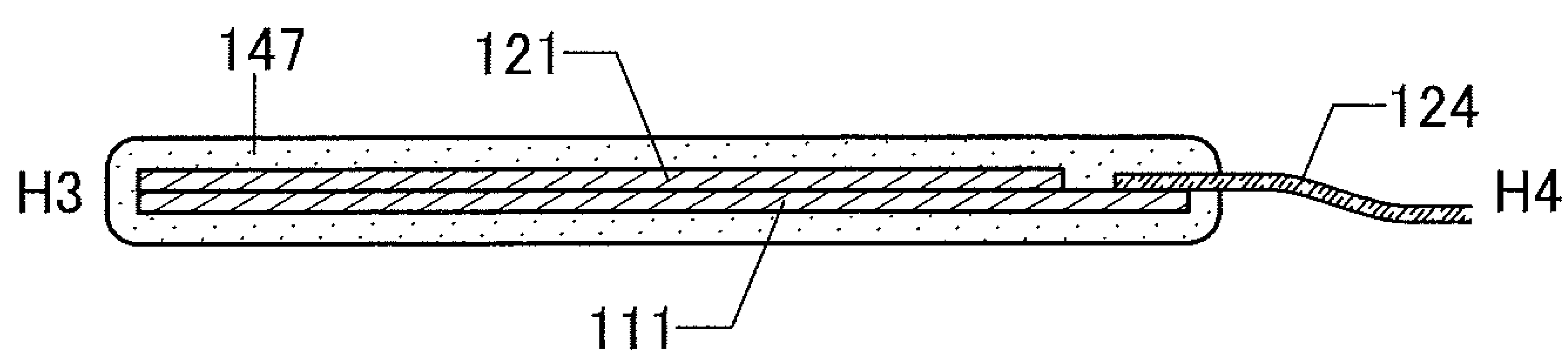

FIG. 19

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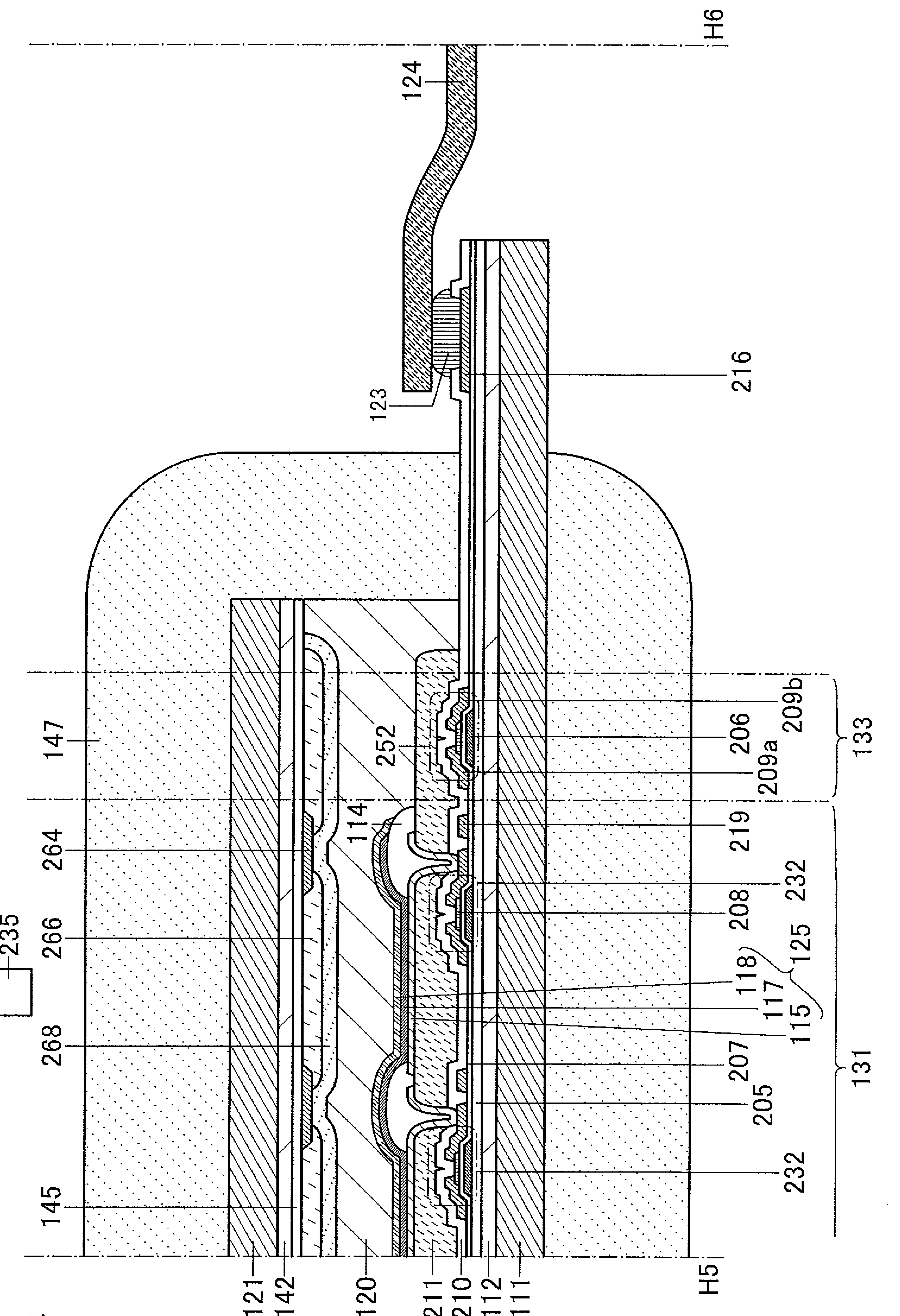
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FIG. 20A

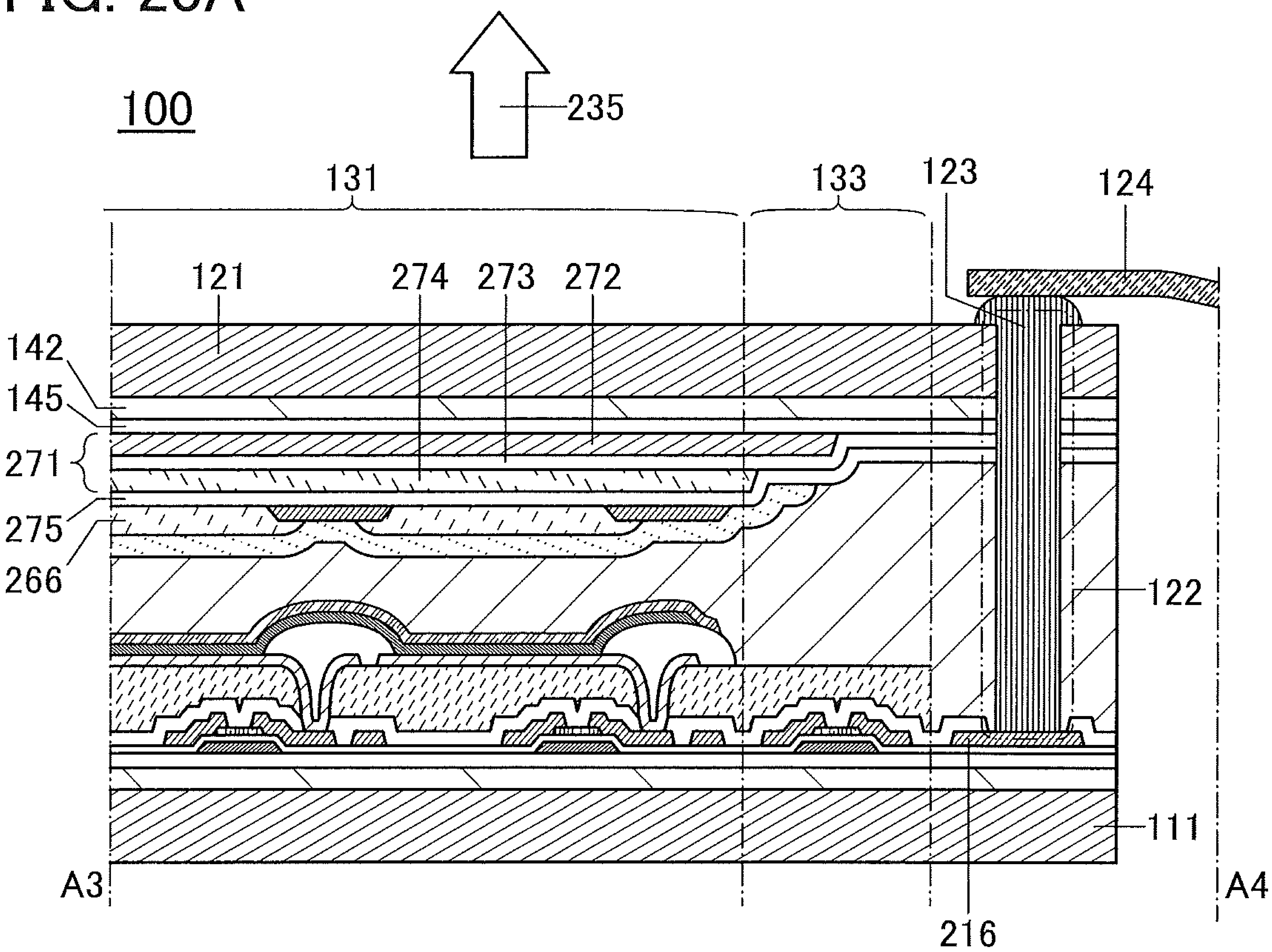


FIG. 20B

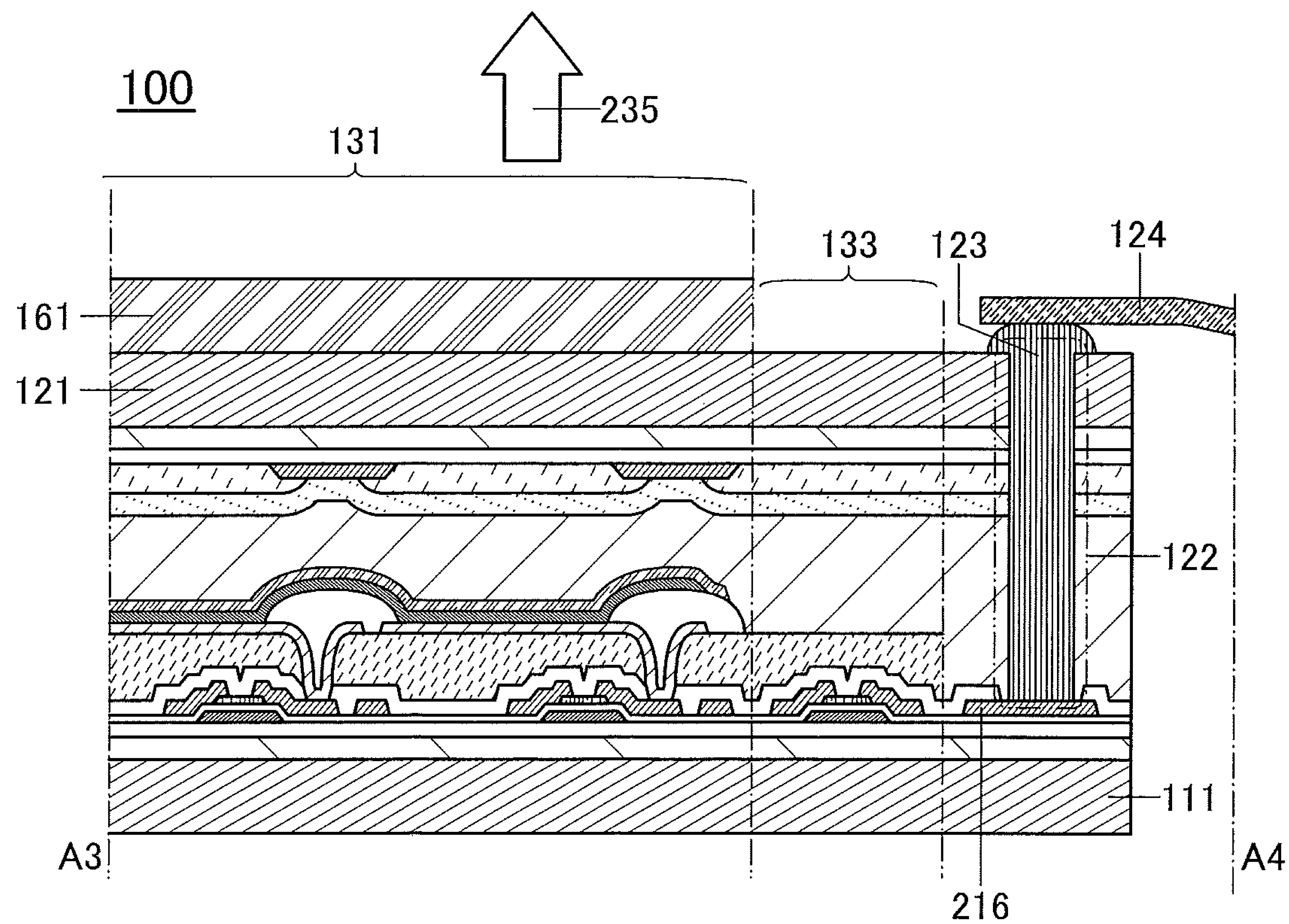


FIG. 21A

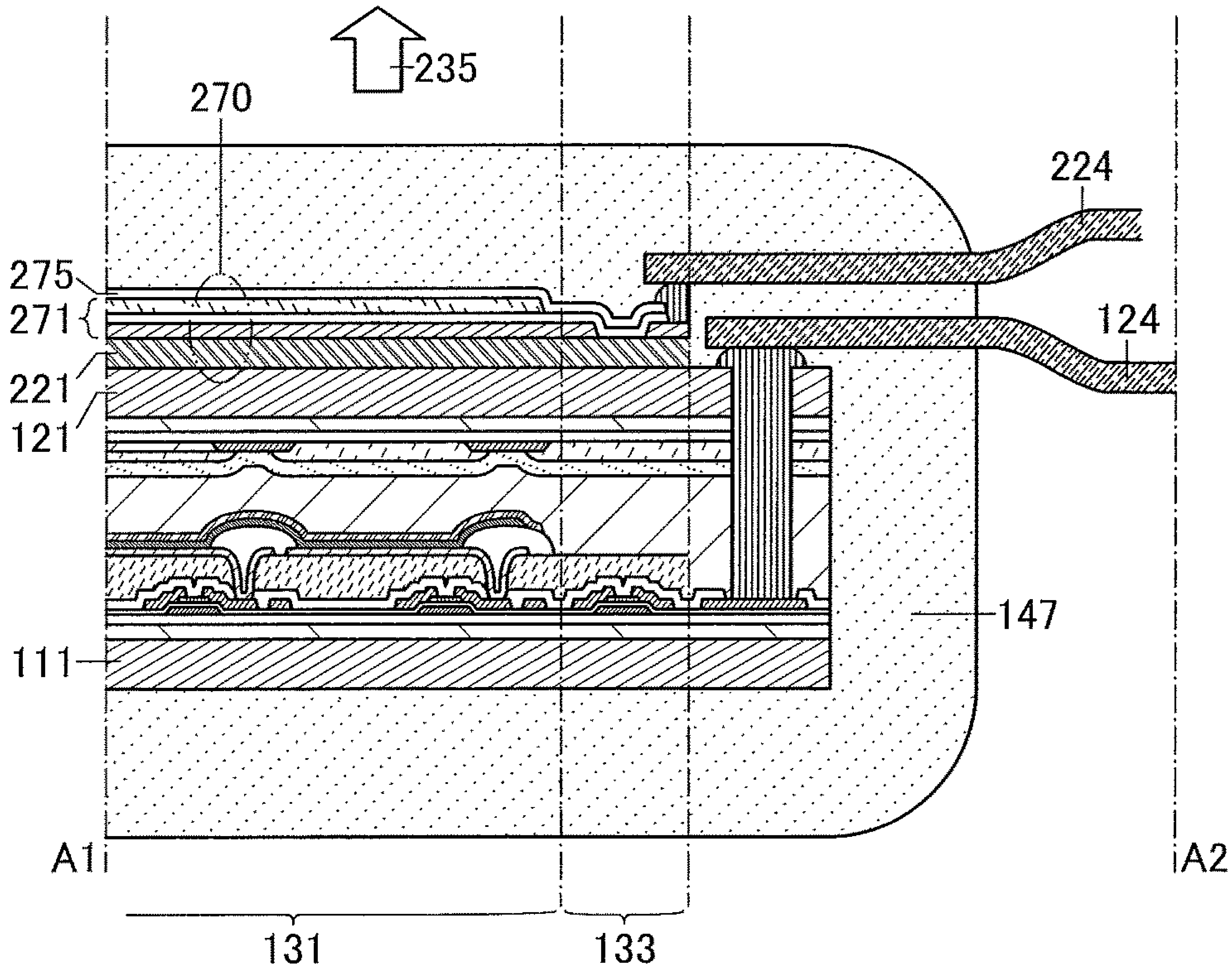
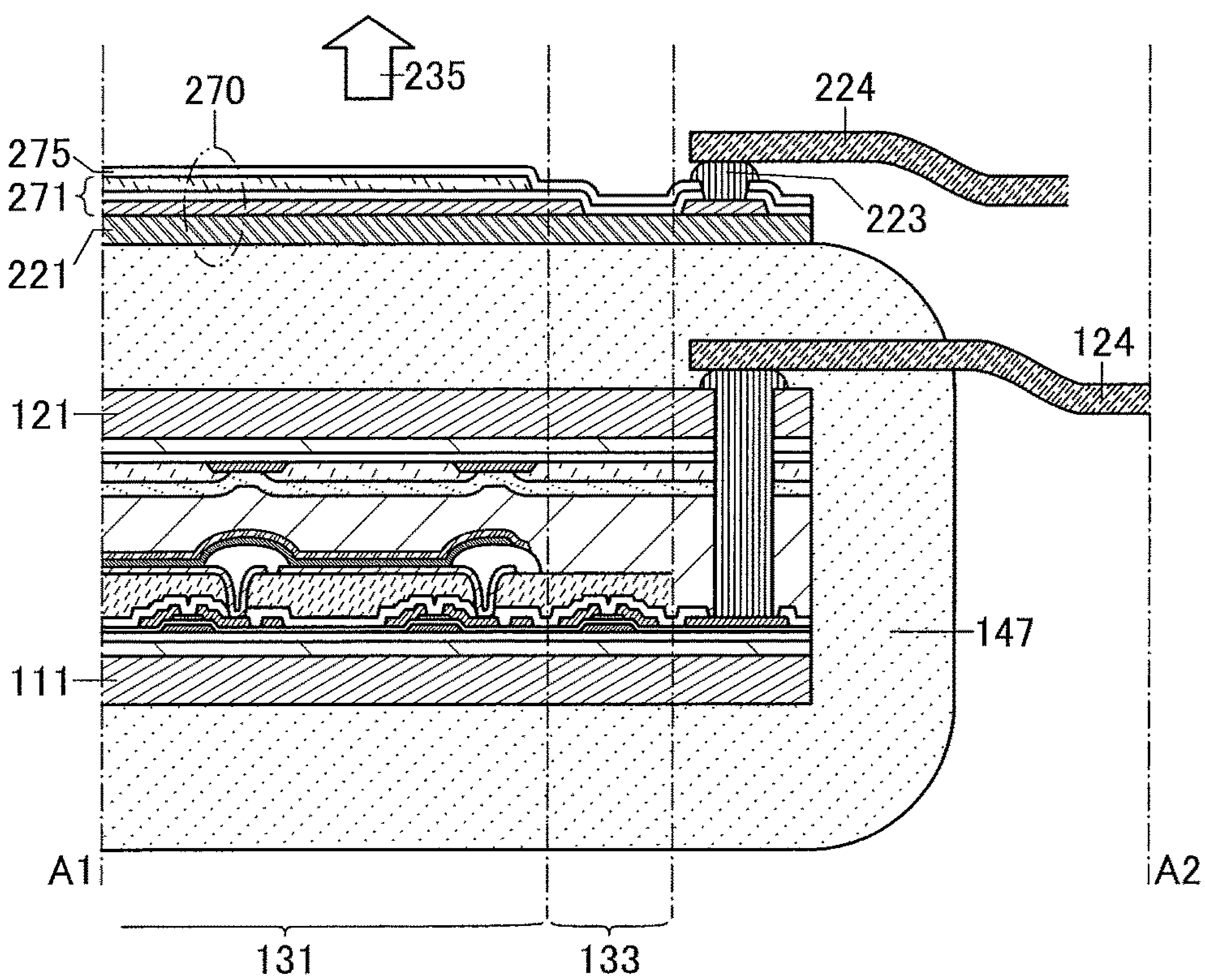


FIG. 21B



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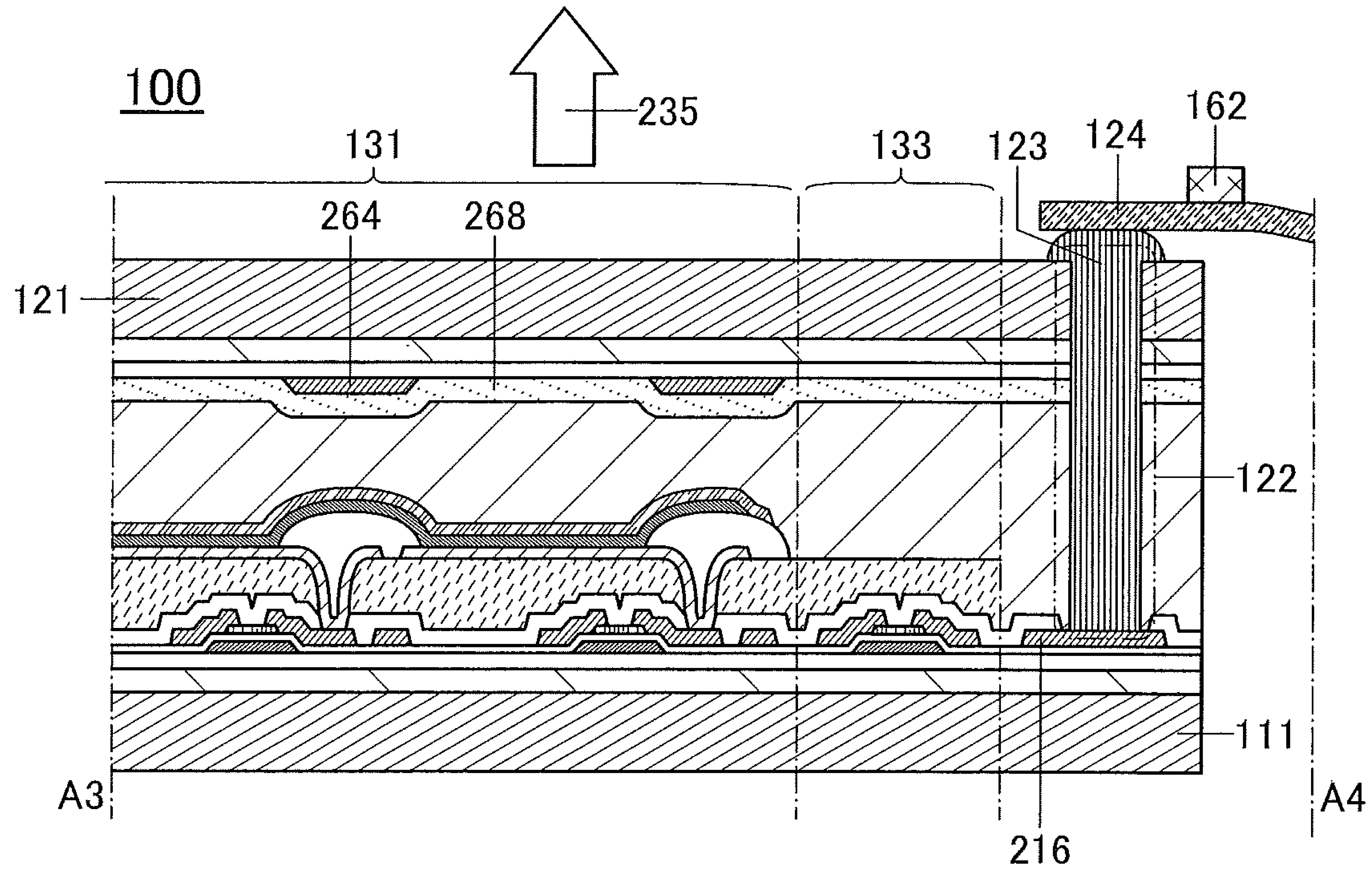


FIG. 22B

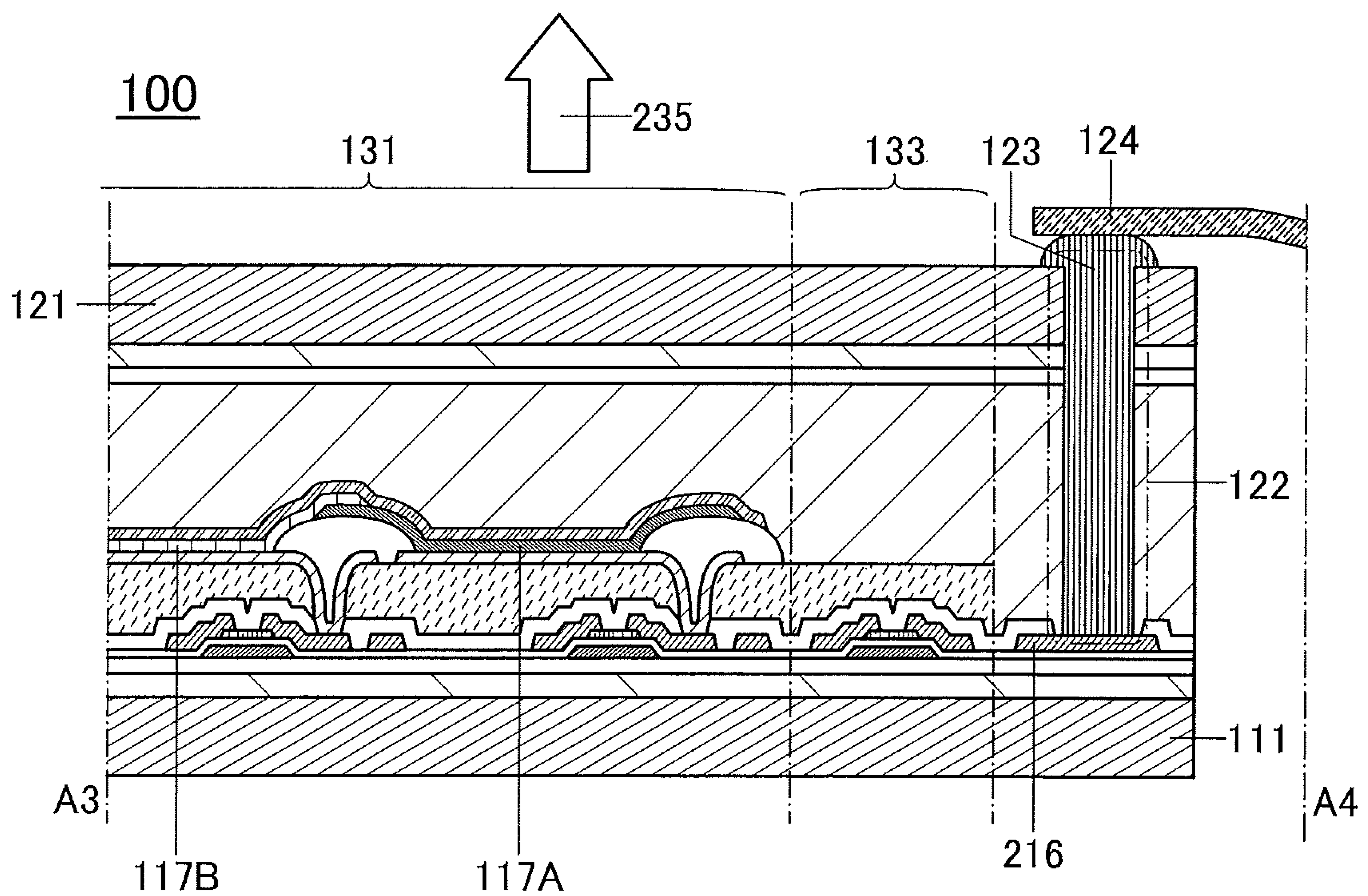


FIG. 23

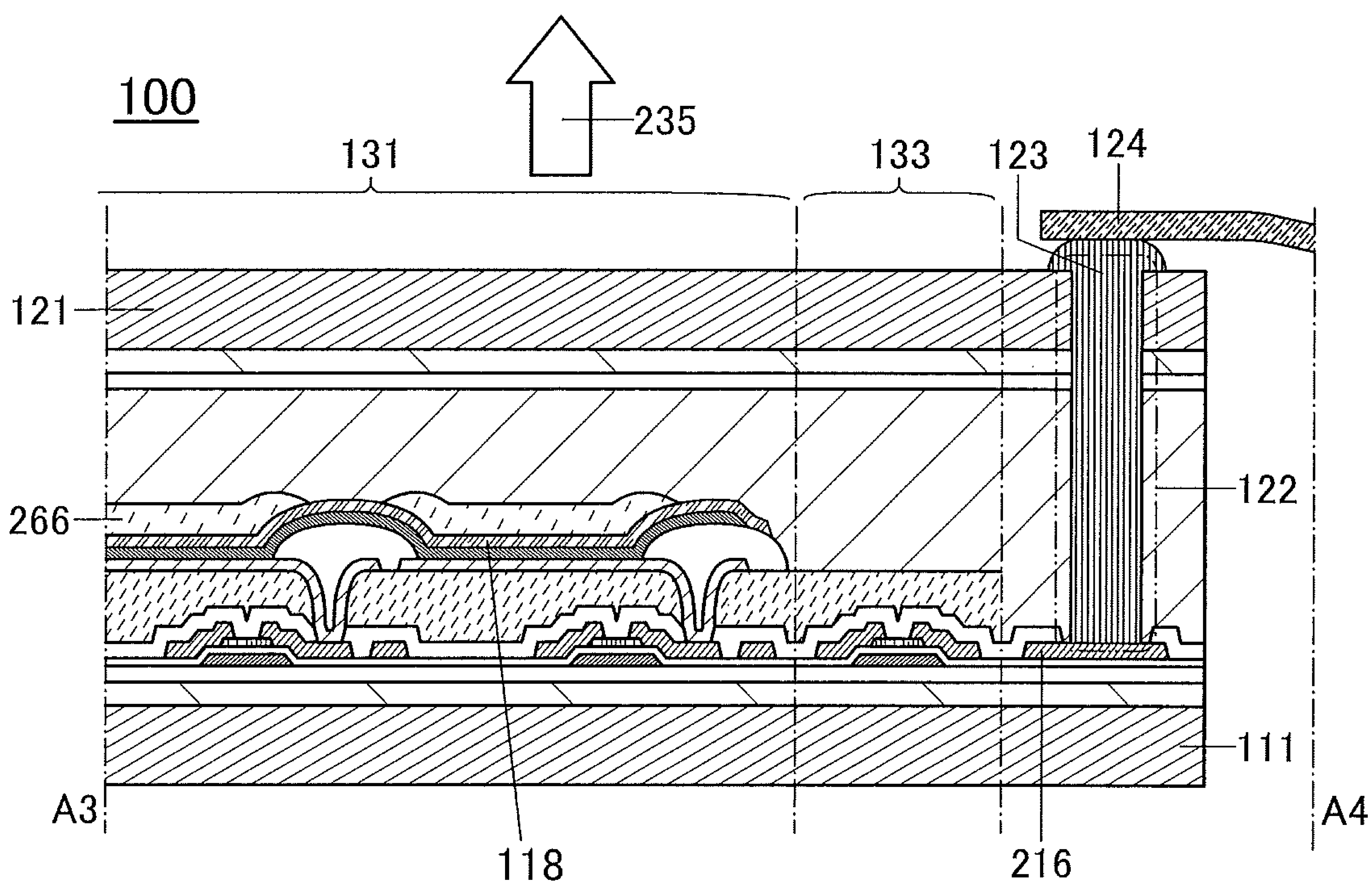


FIG. 24

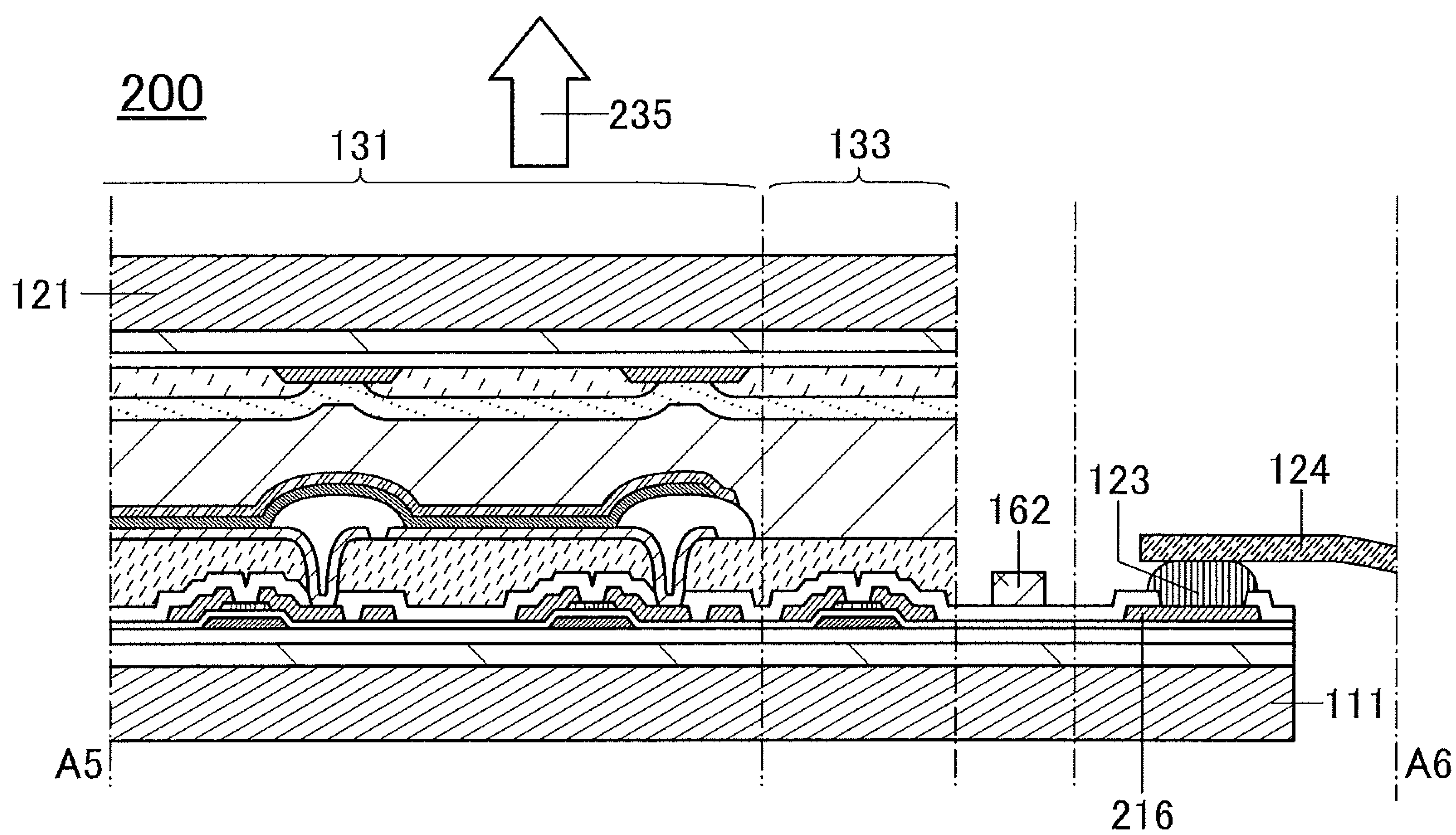


FIG. 25A

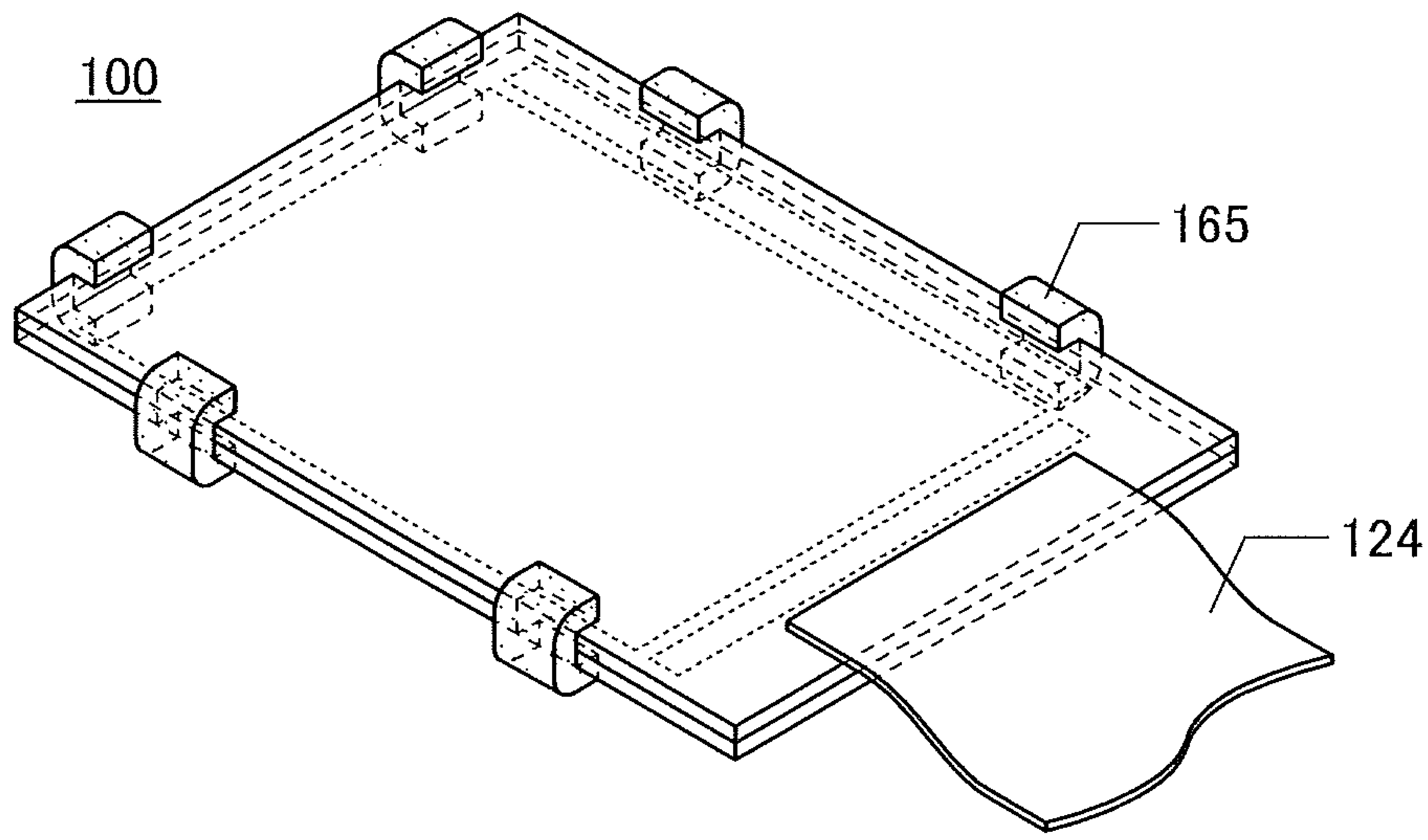


FIG. 25C

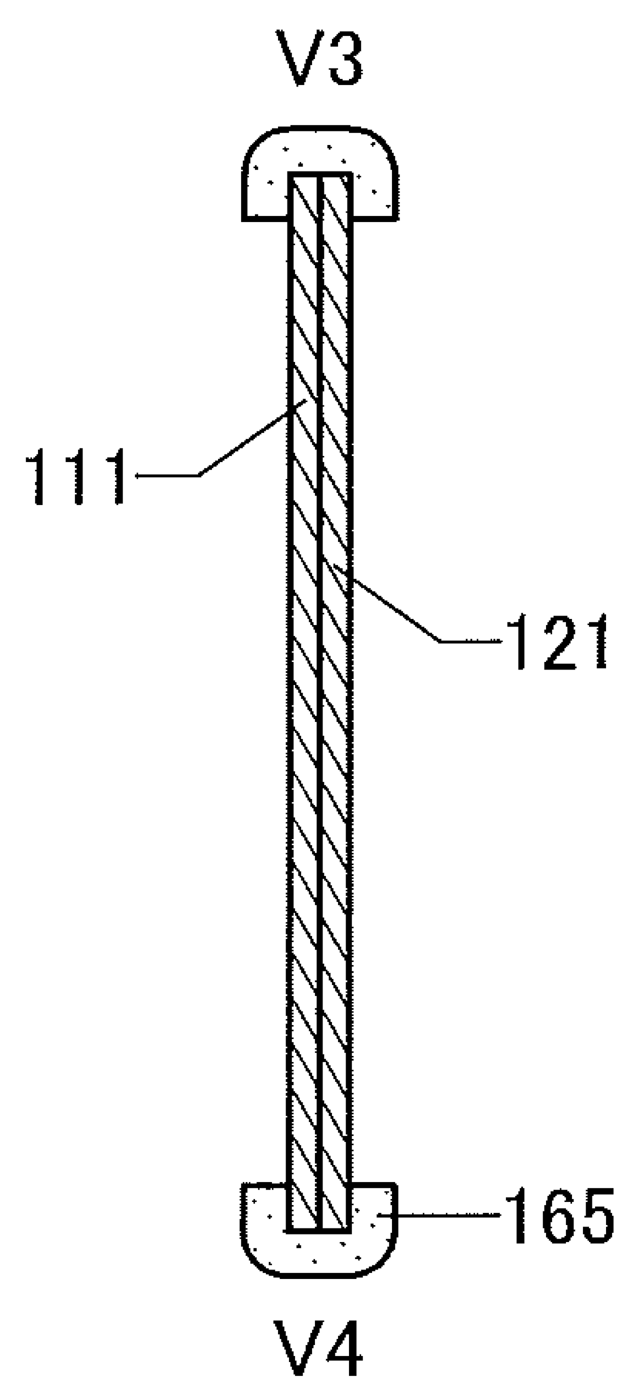


FIG. 25B

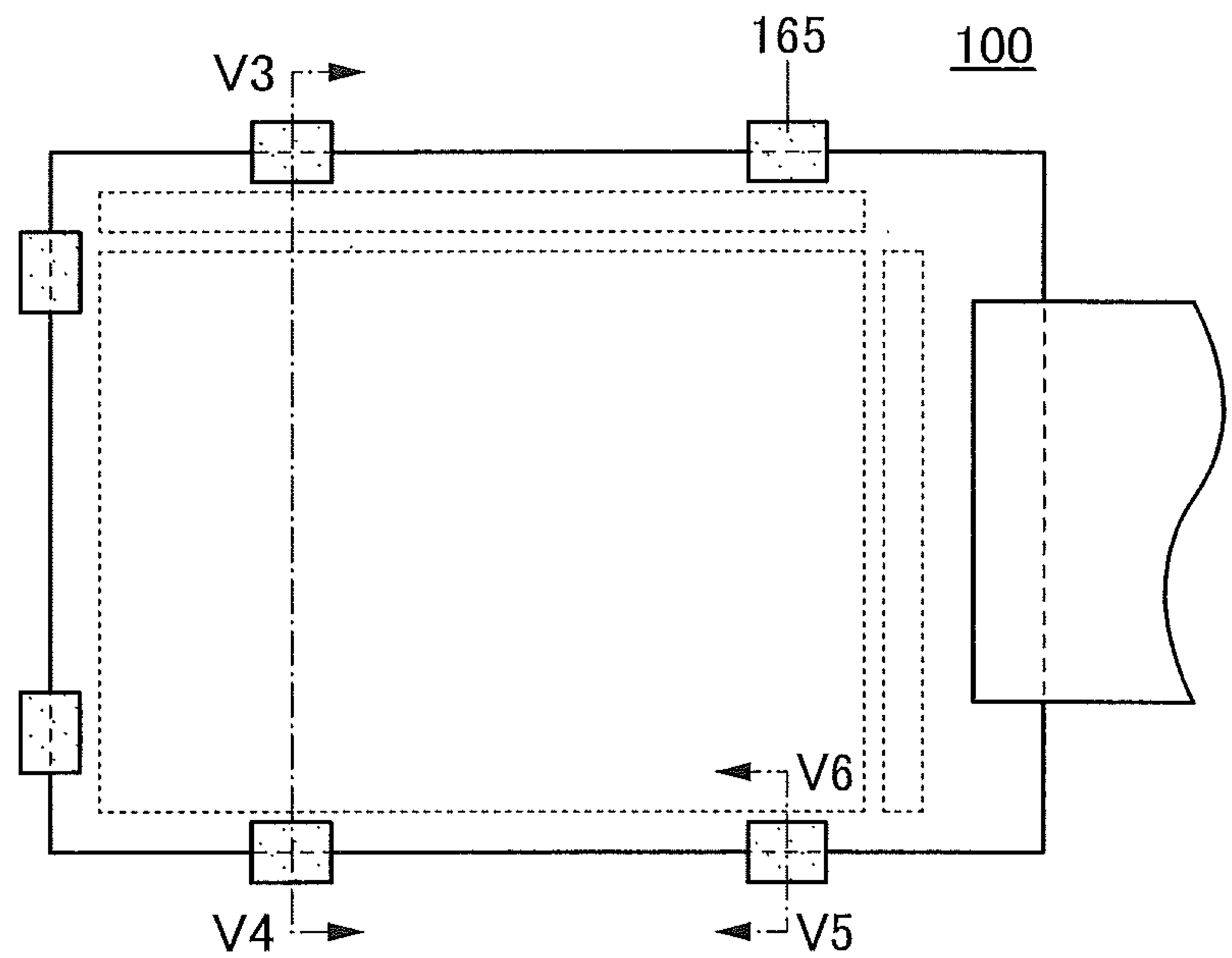


FIG. 25D

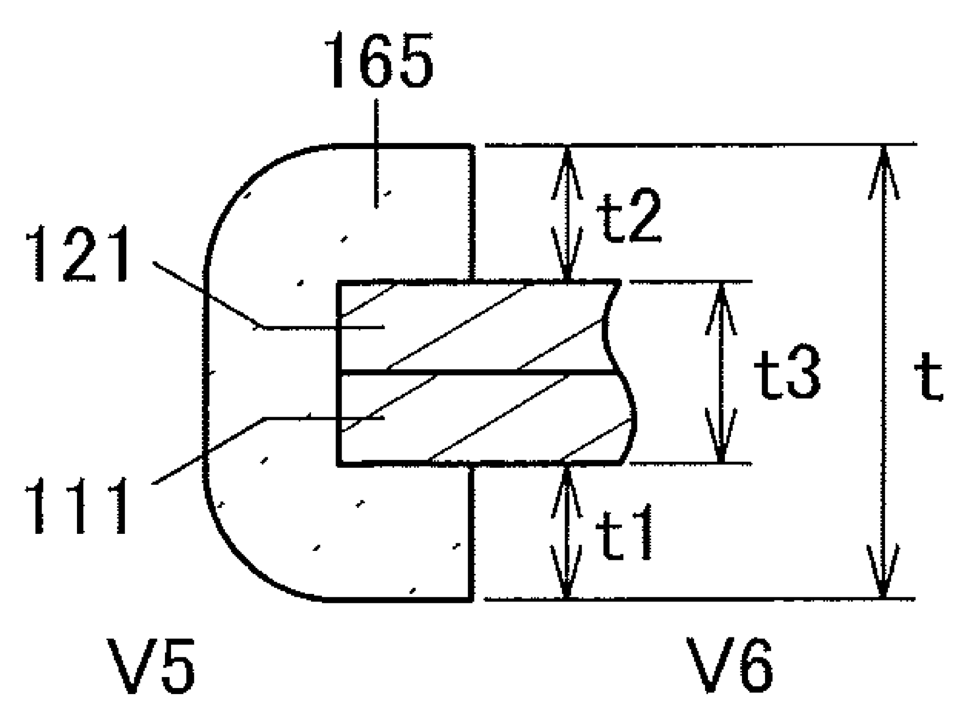


FIG. 25E

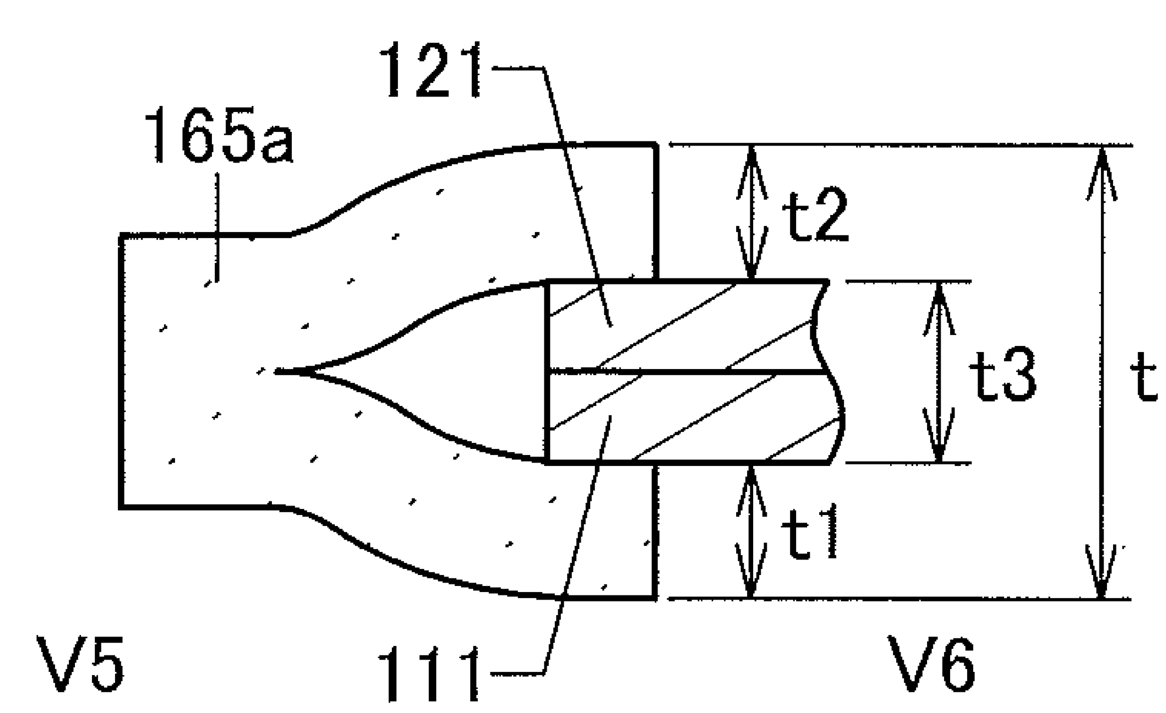


FIG. 26A

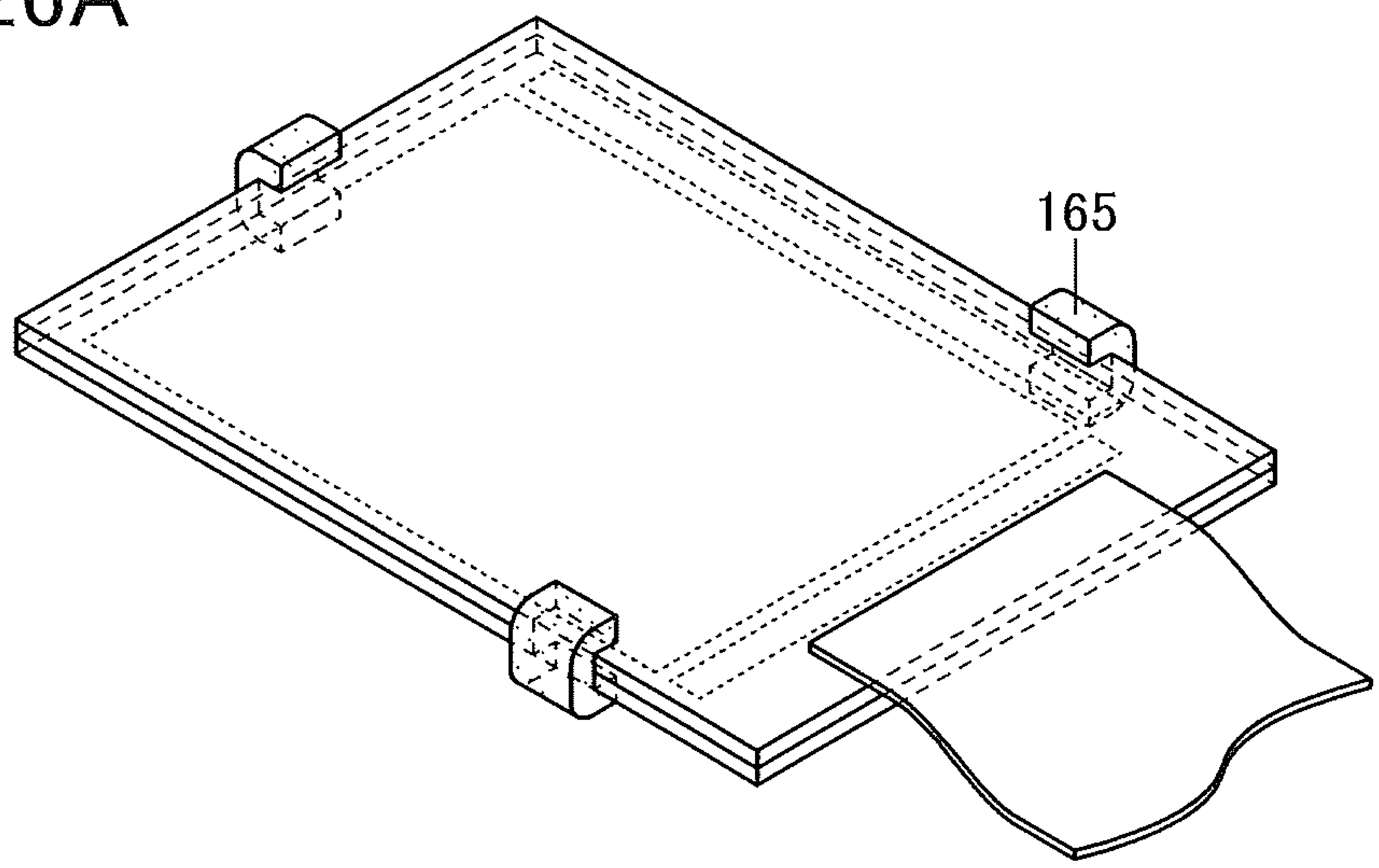


FIG. 26B

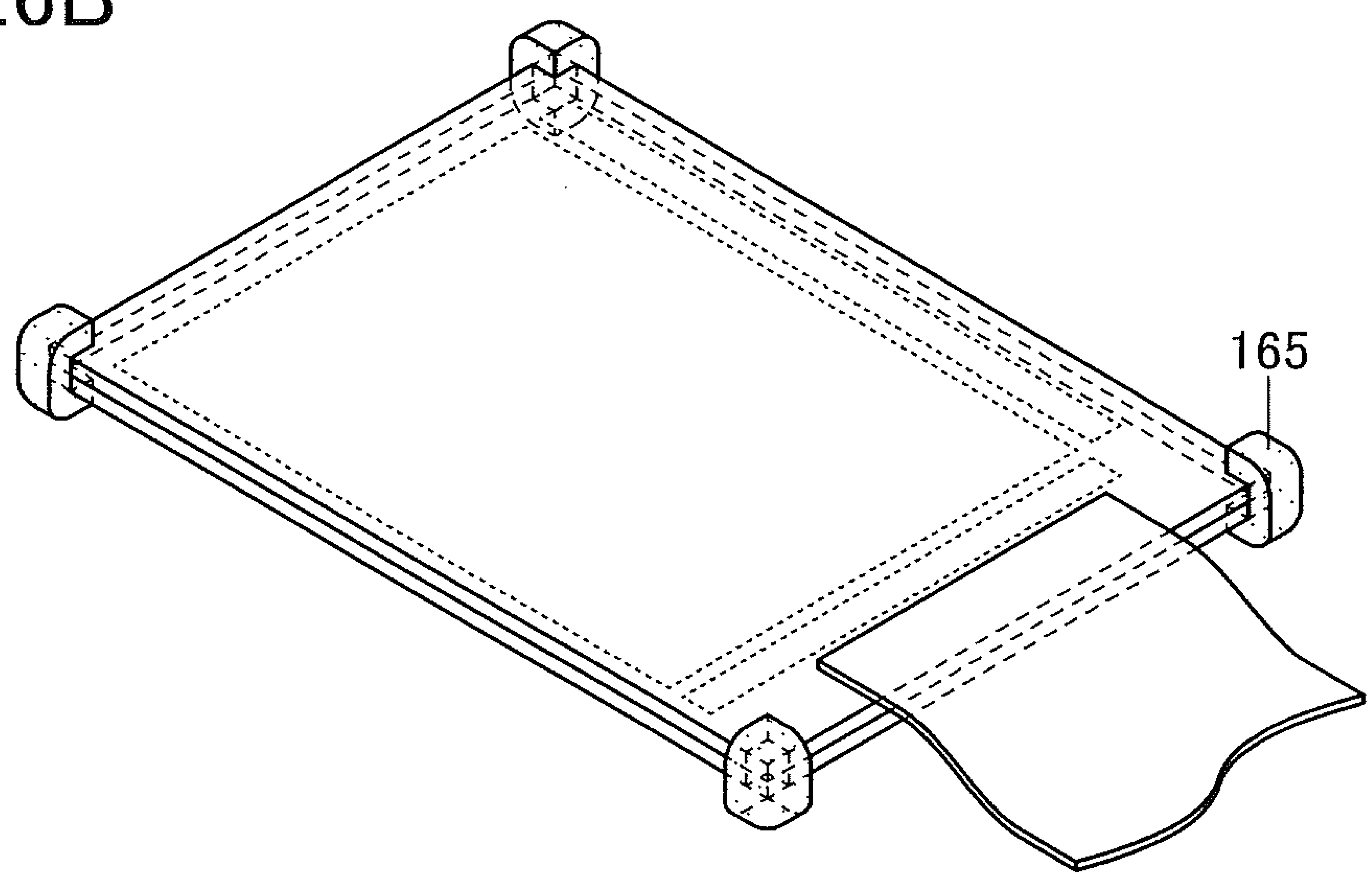


FIG. 26C

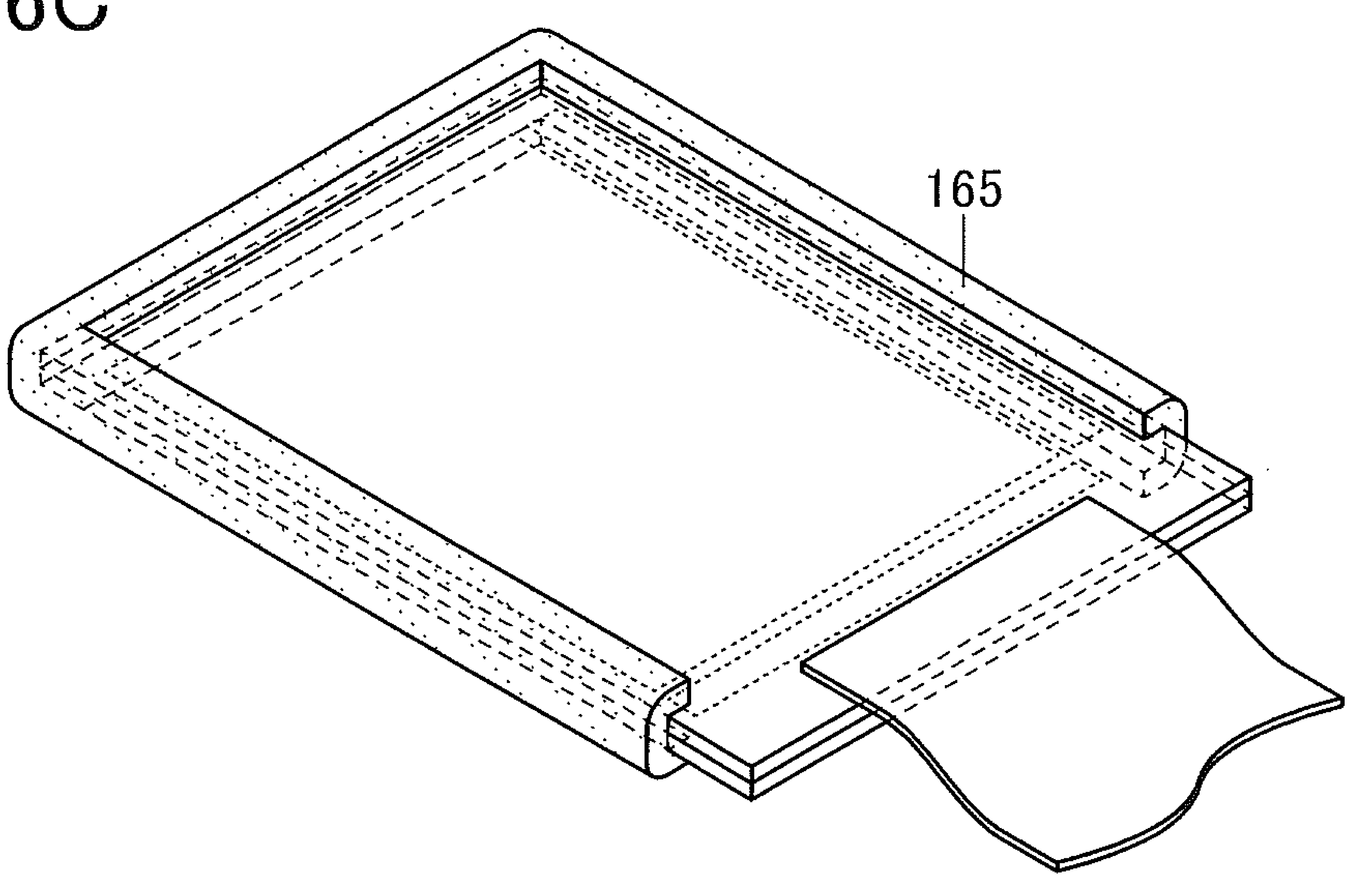


FIG. 27A

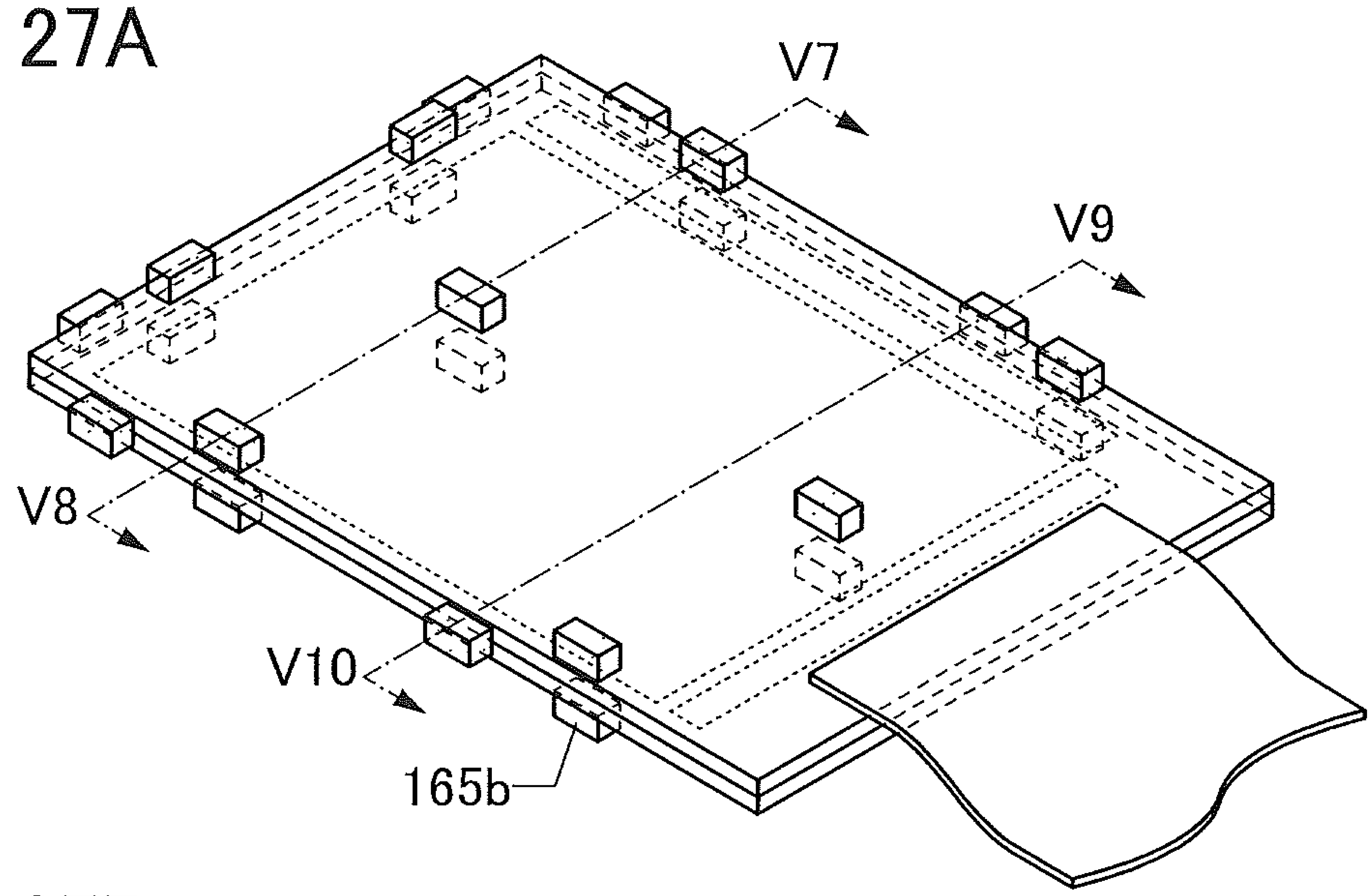


FIG. 27B

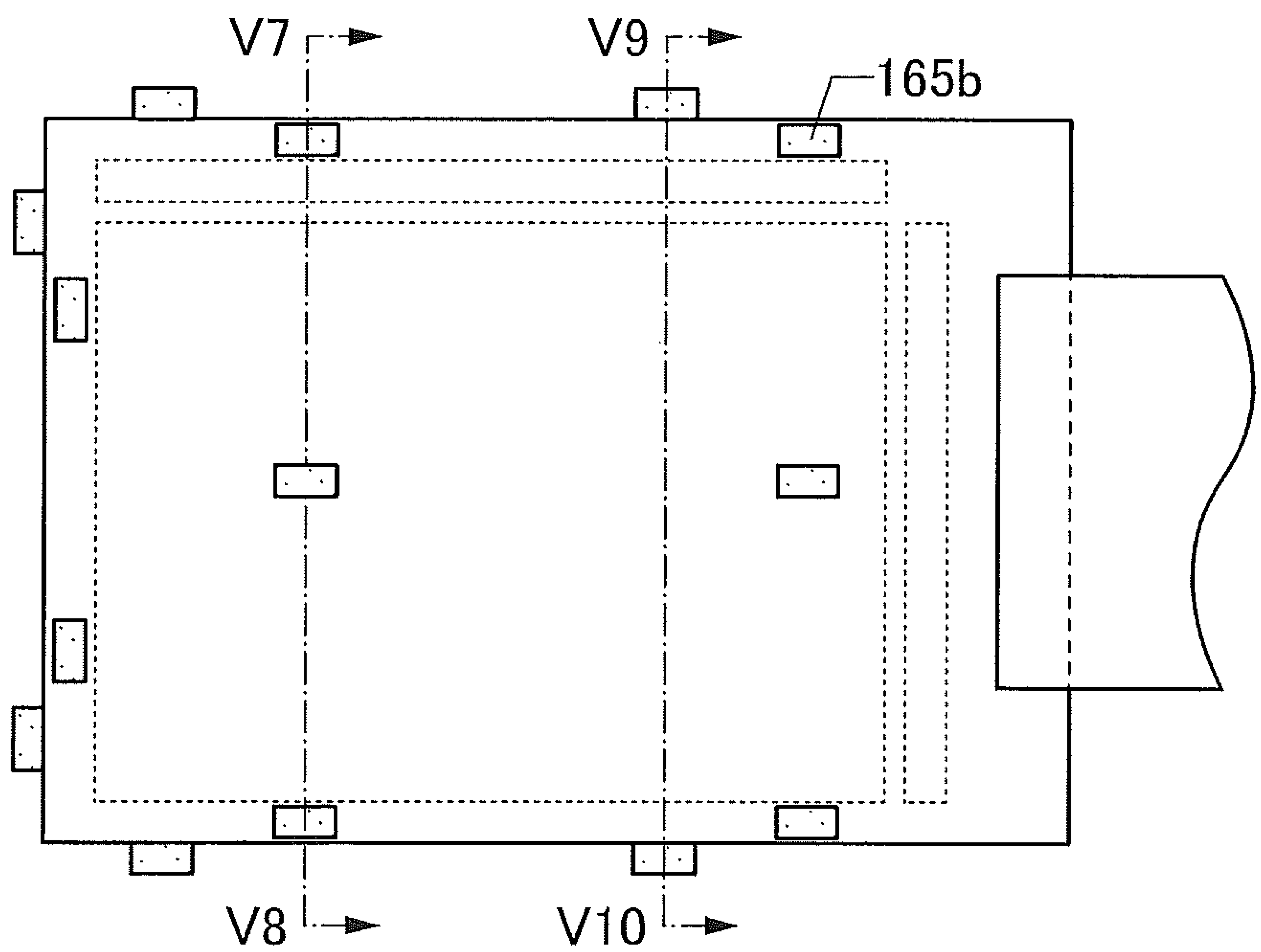


FIG. 27C

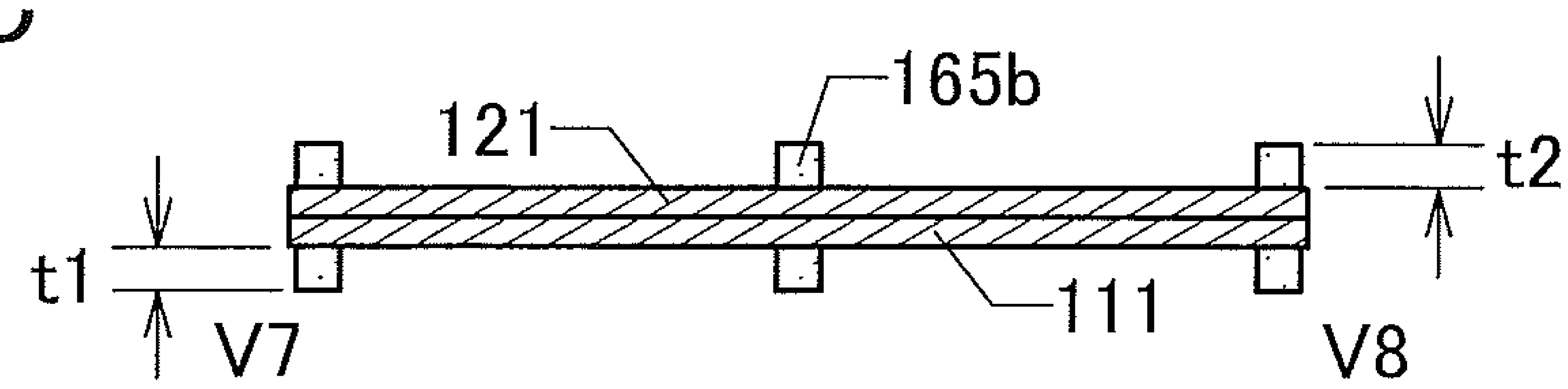


FIG. 27D

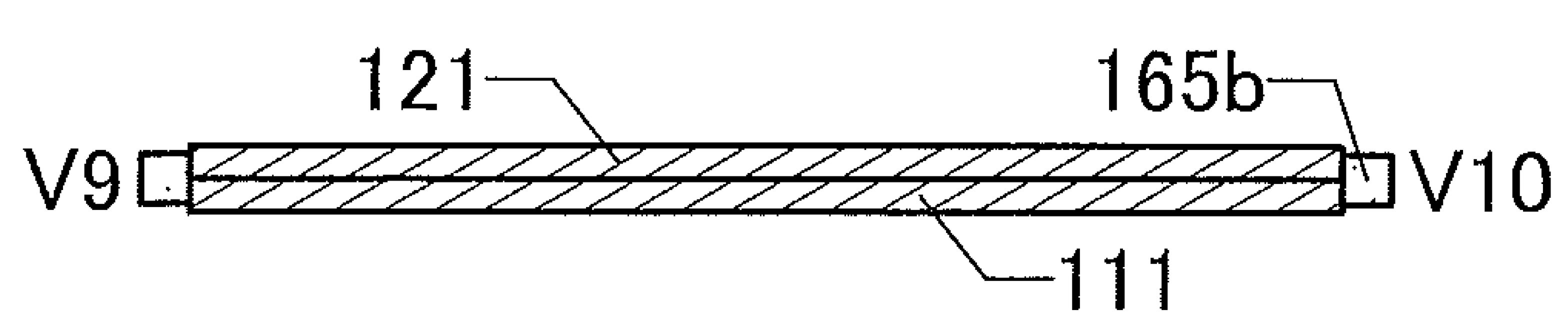


FIG. 28A

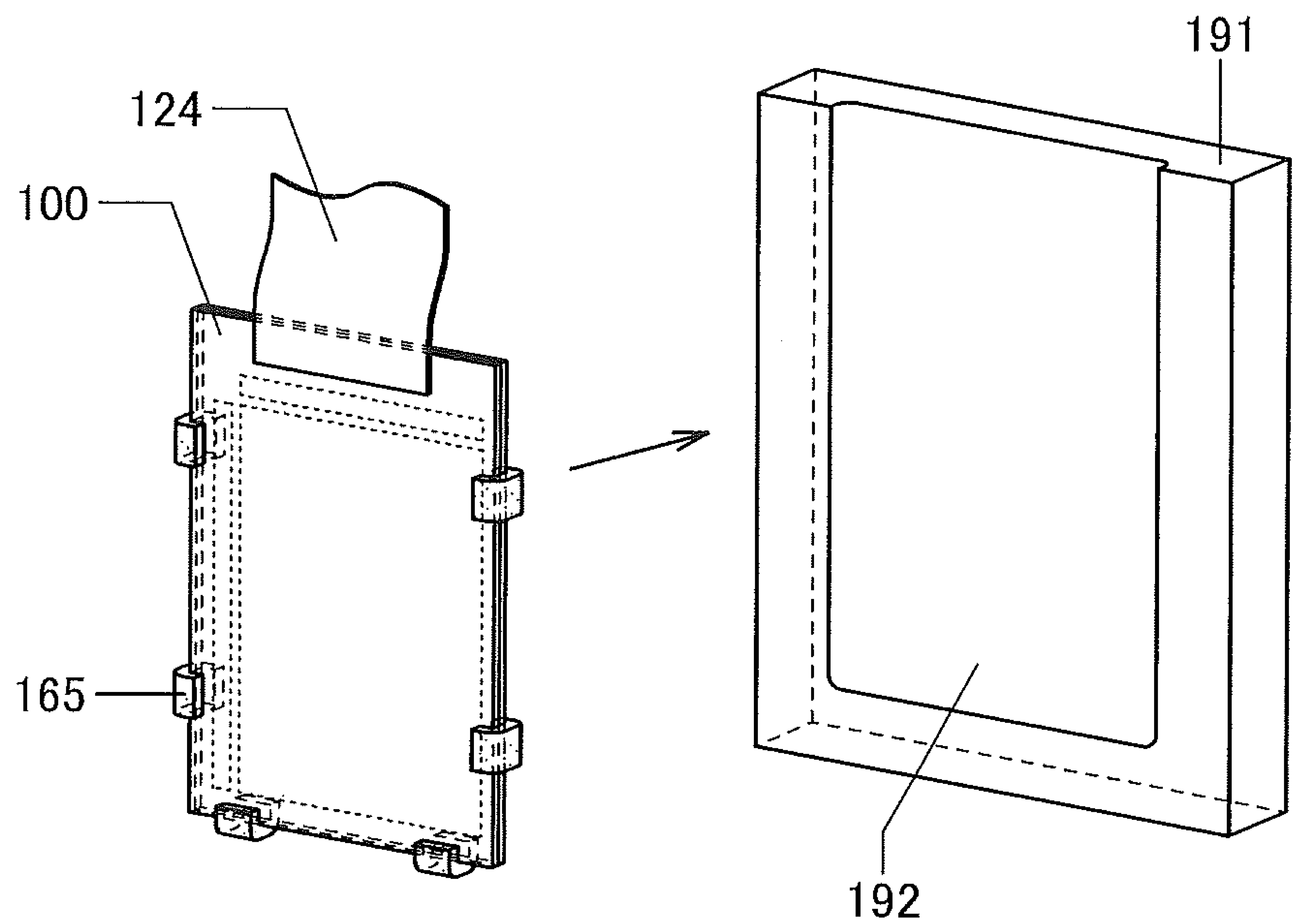


FIG. 28B

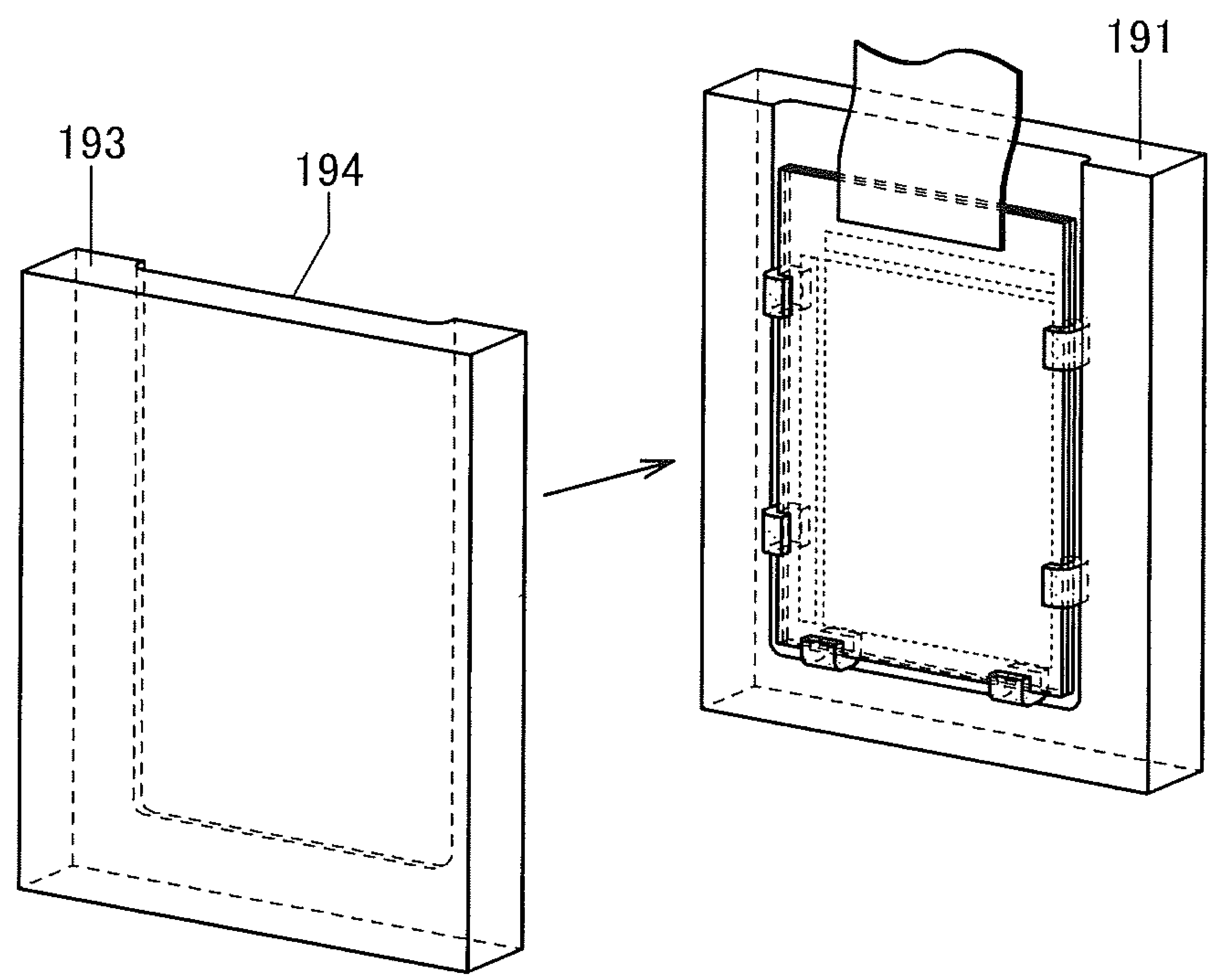


FIG. 29A

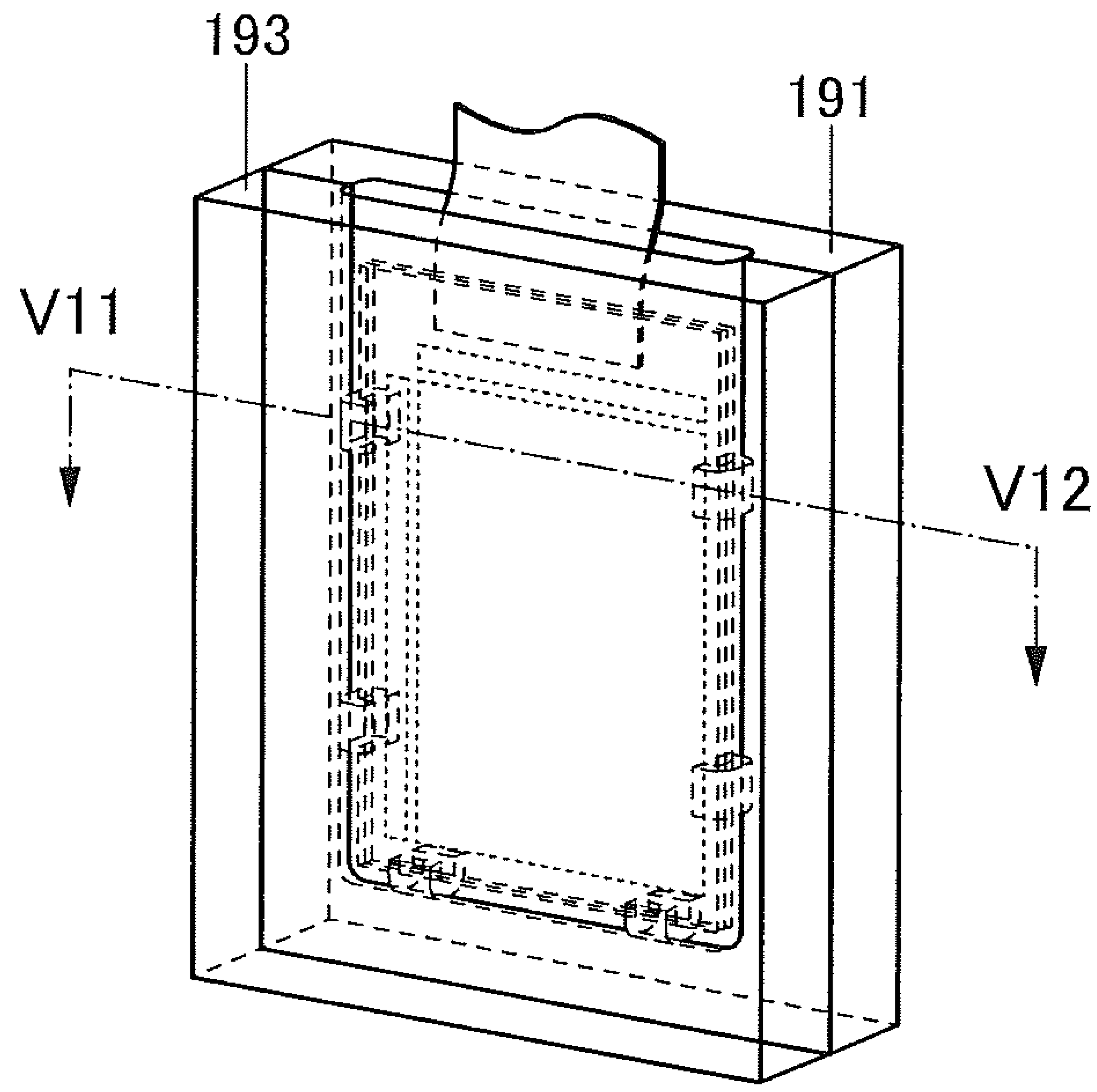


FIG. 29B

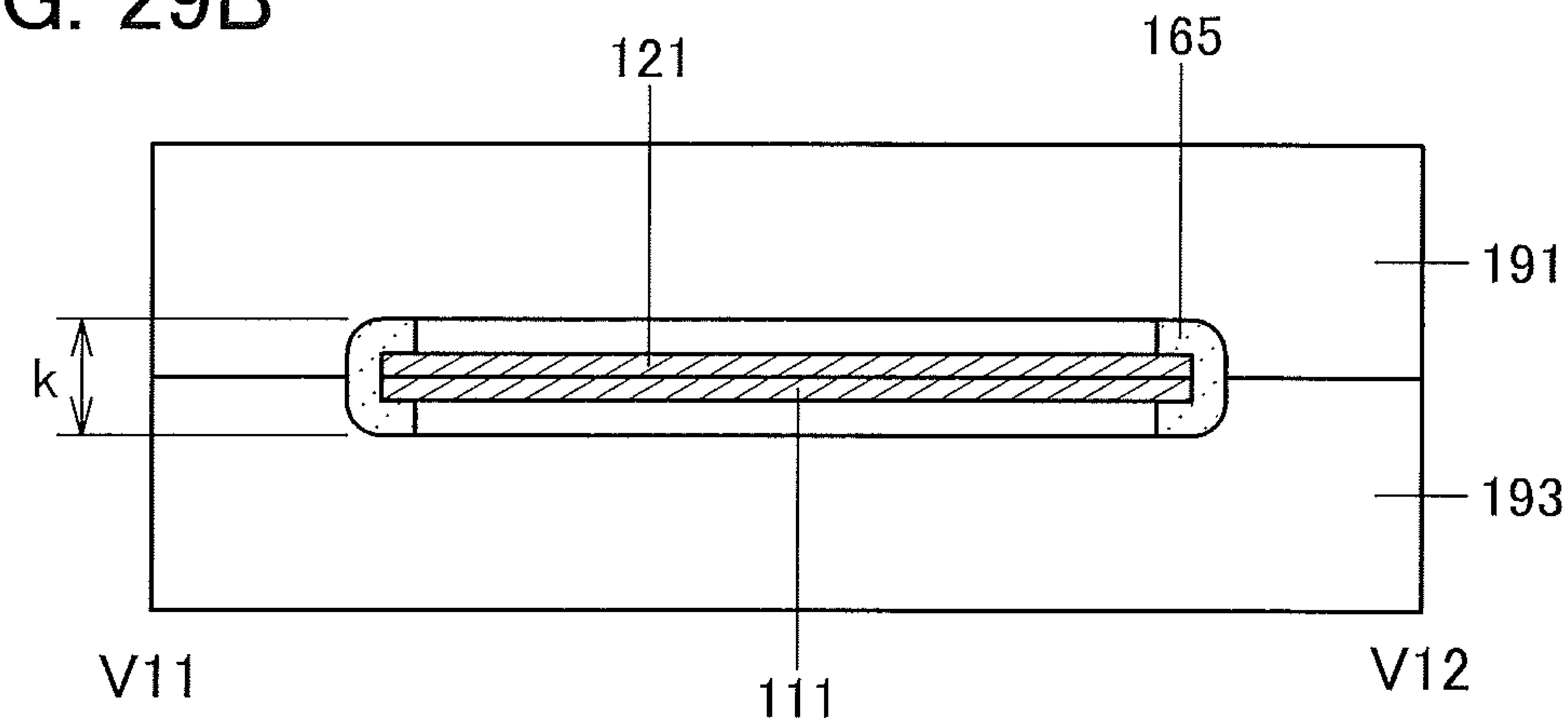


FIG. 29C

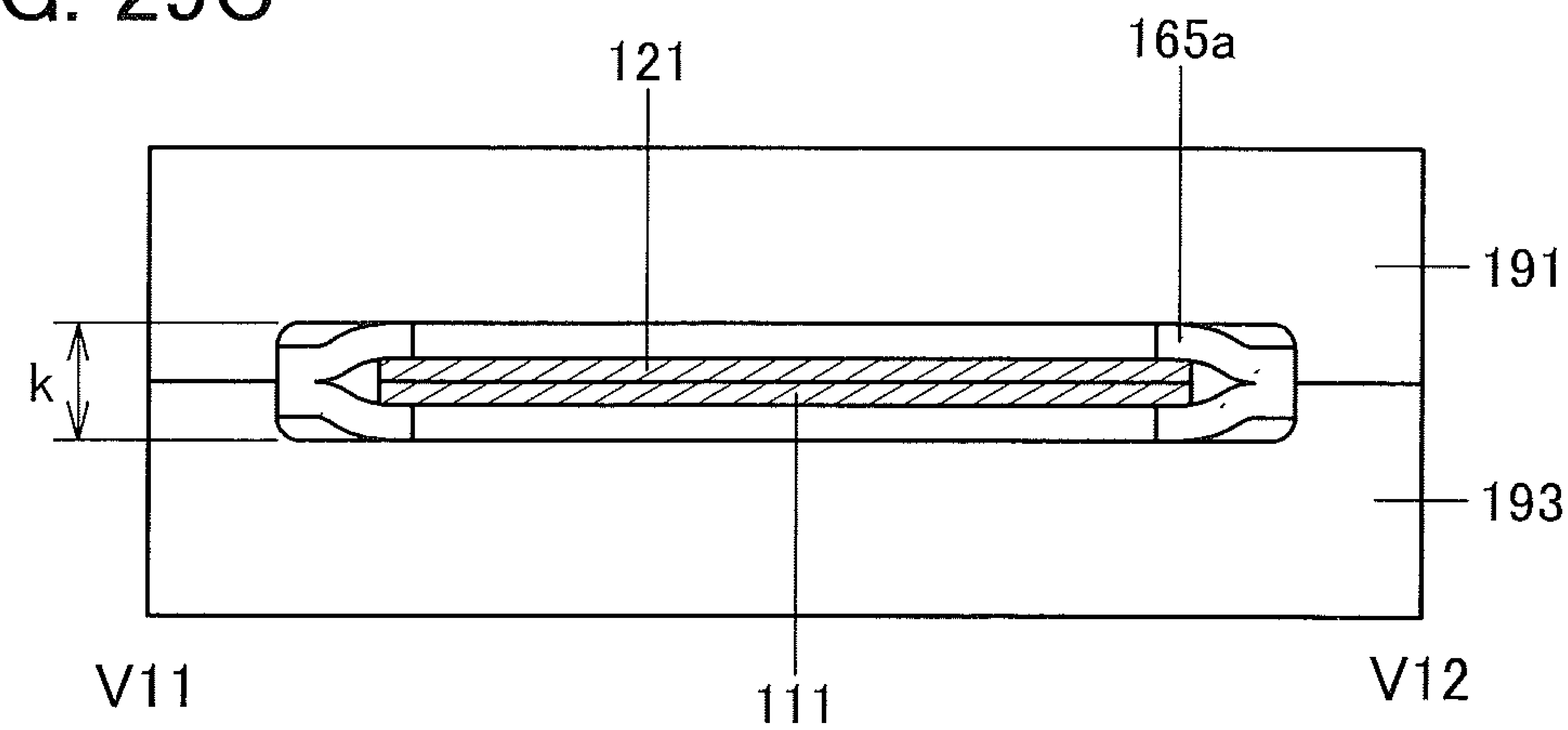


FIG. 30A

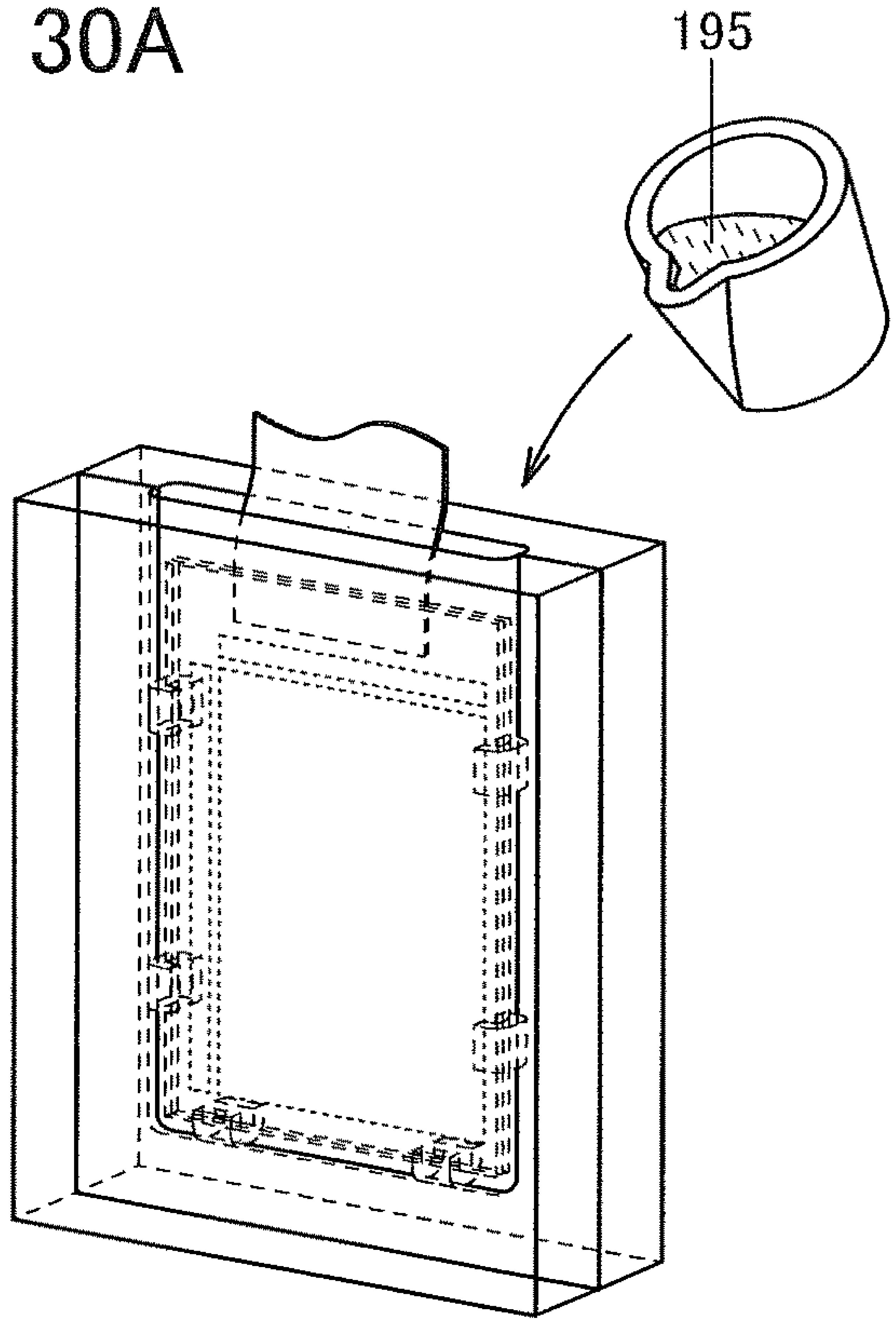


FIG. 30B

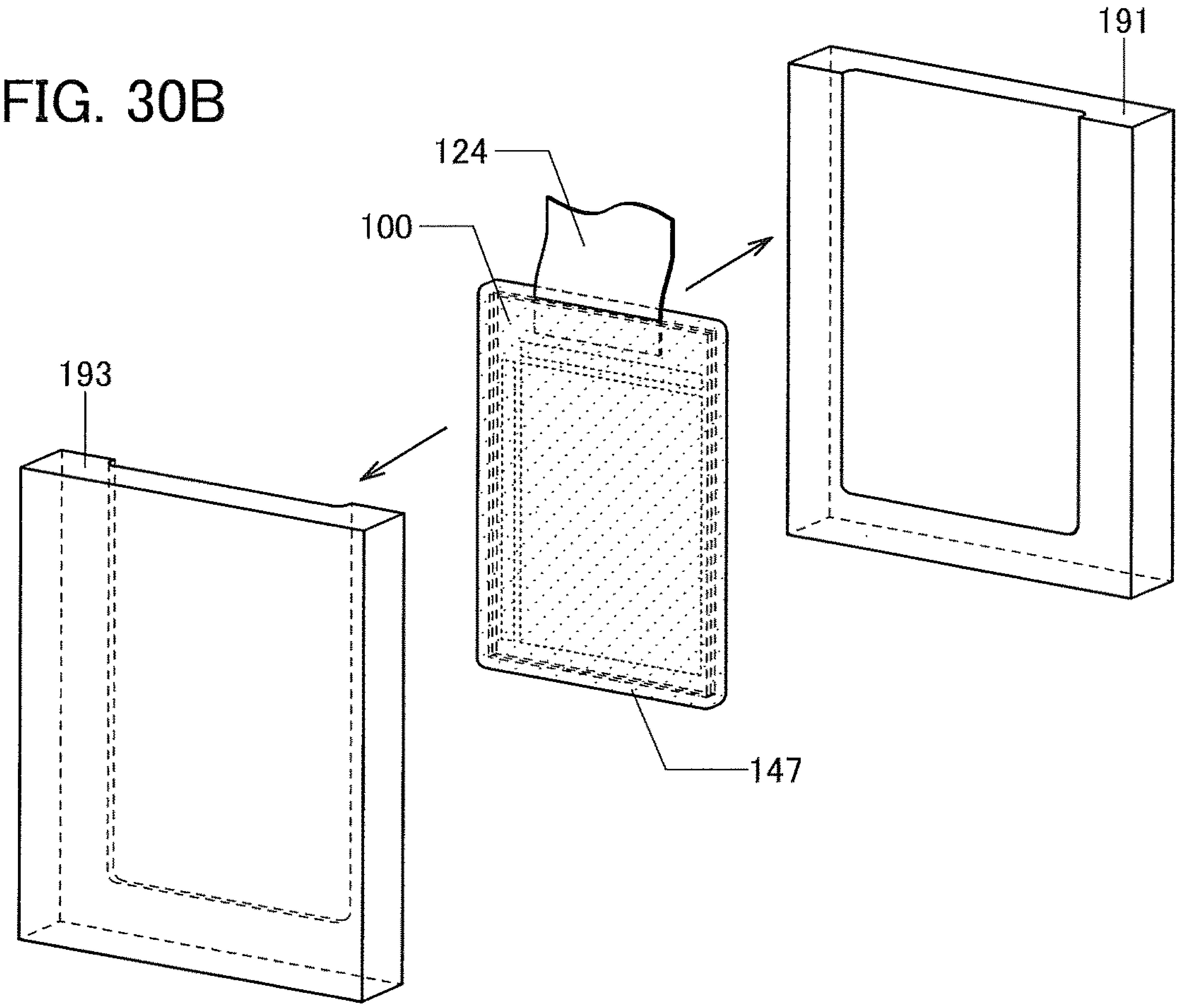


FIG. 31A

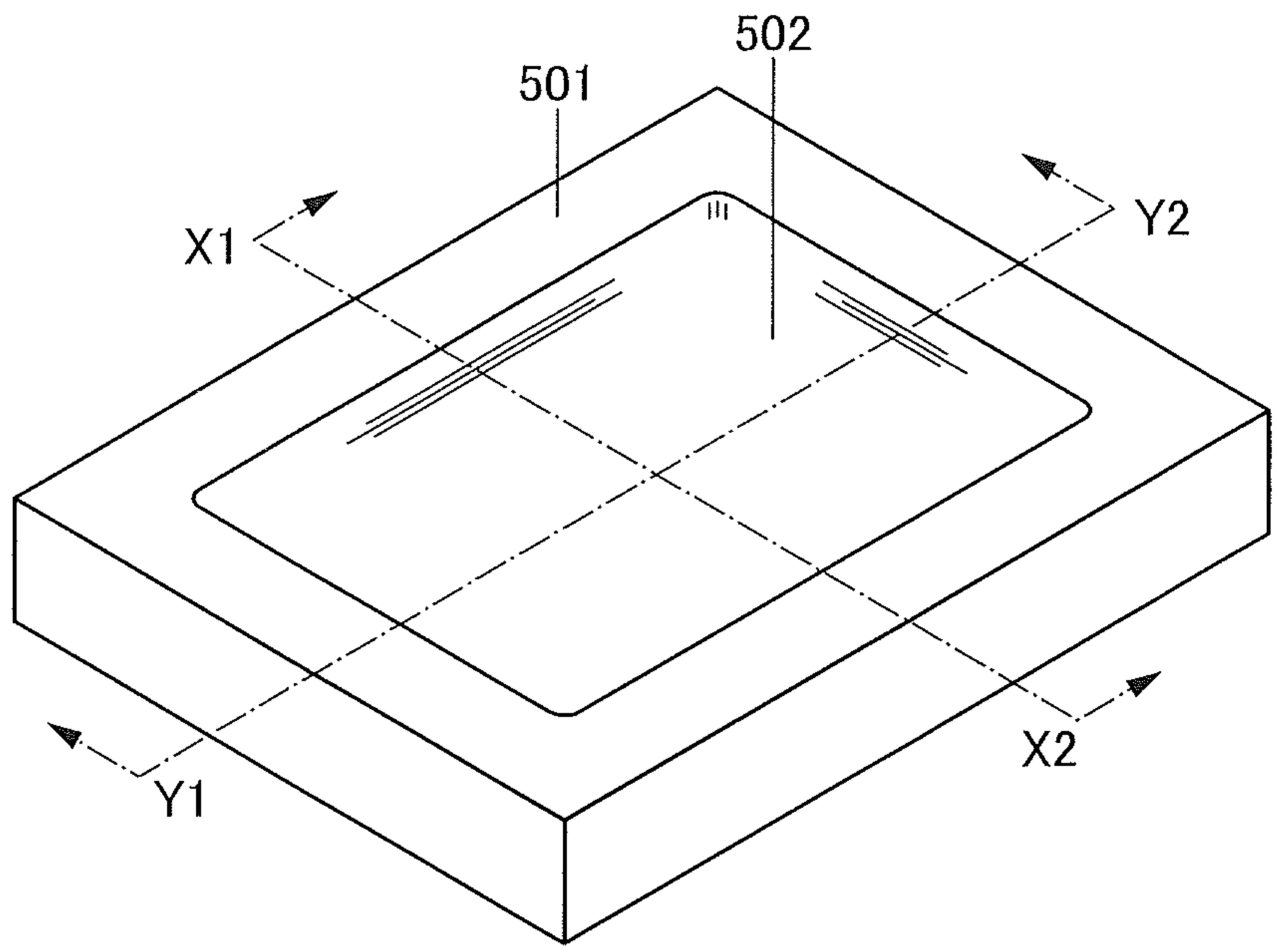


FIG. 31B

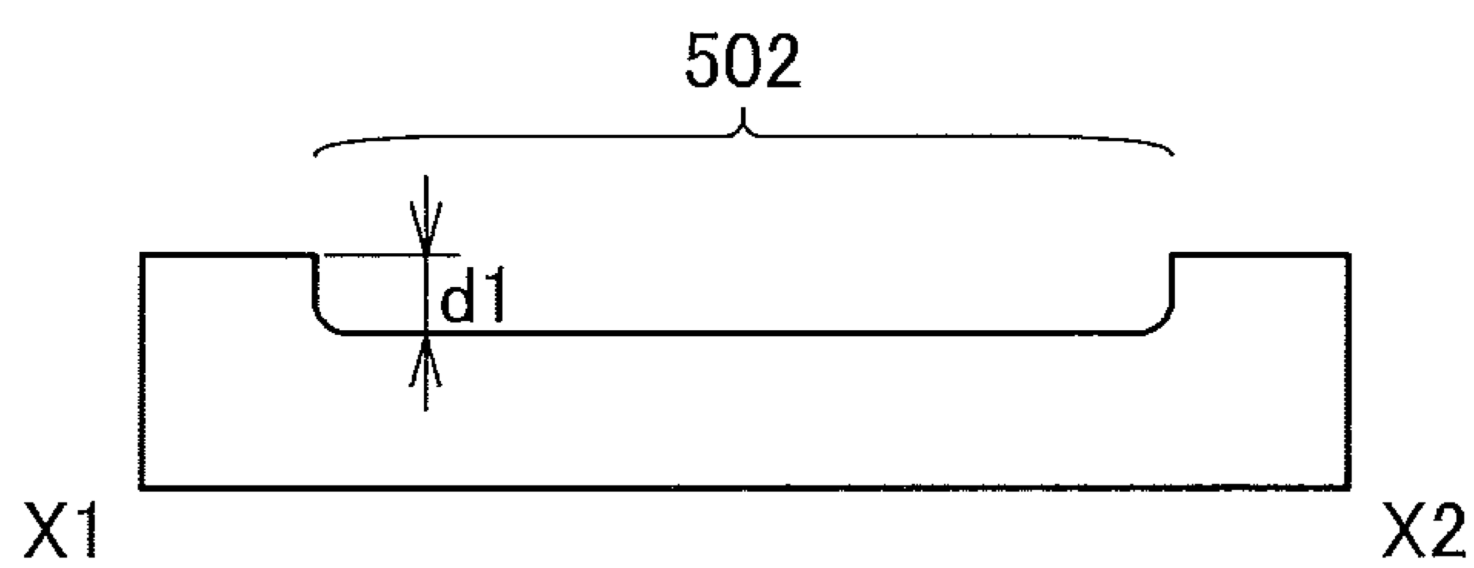


FIG. 31C

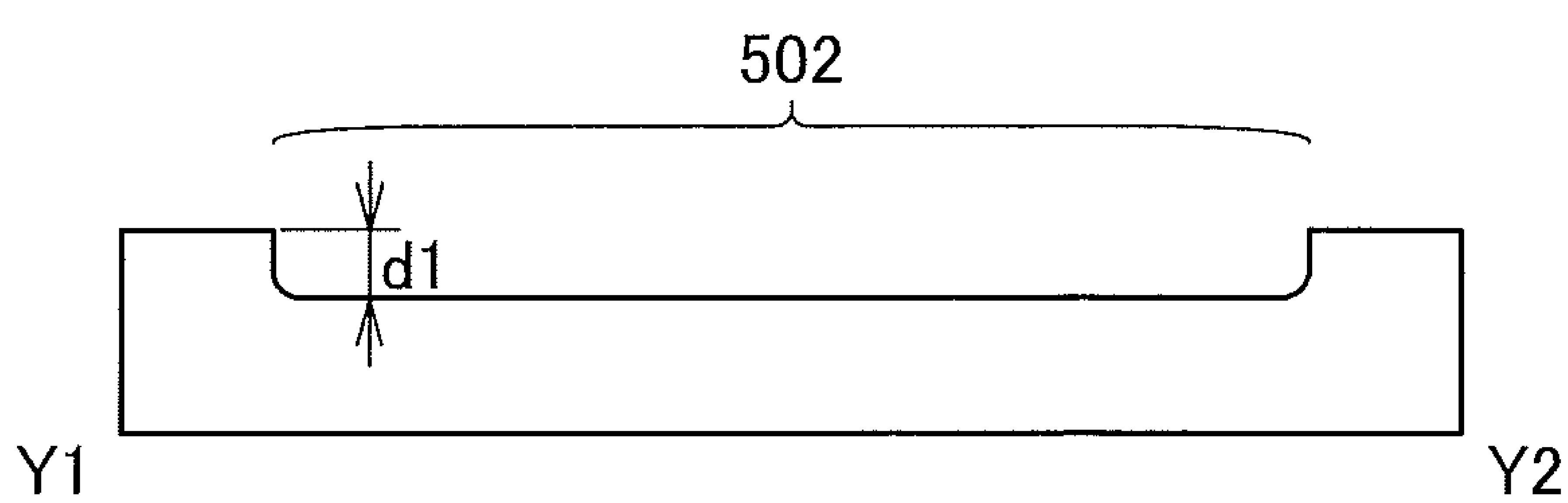


FIG. 32A

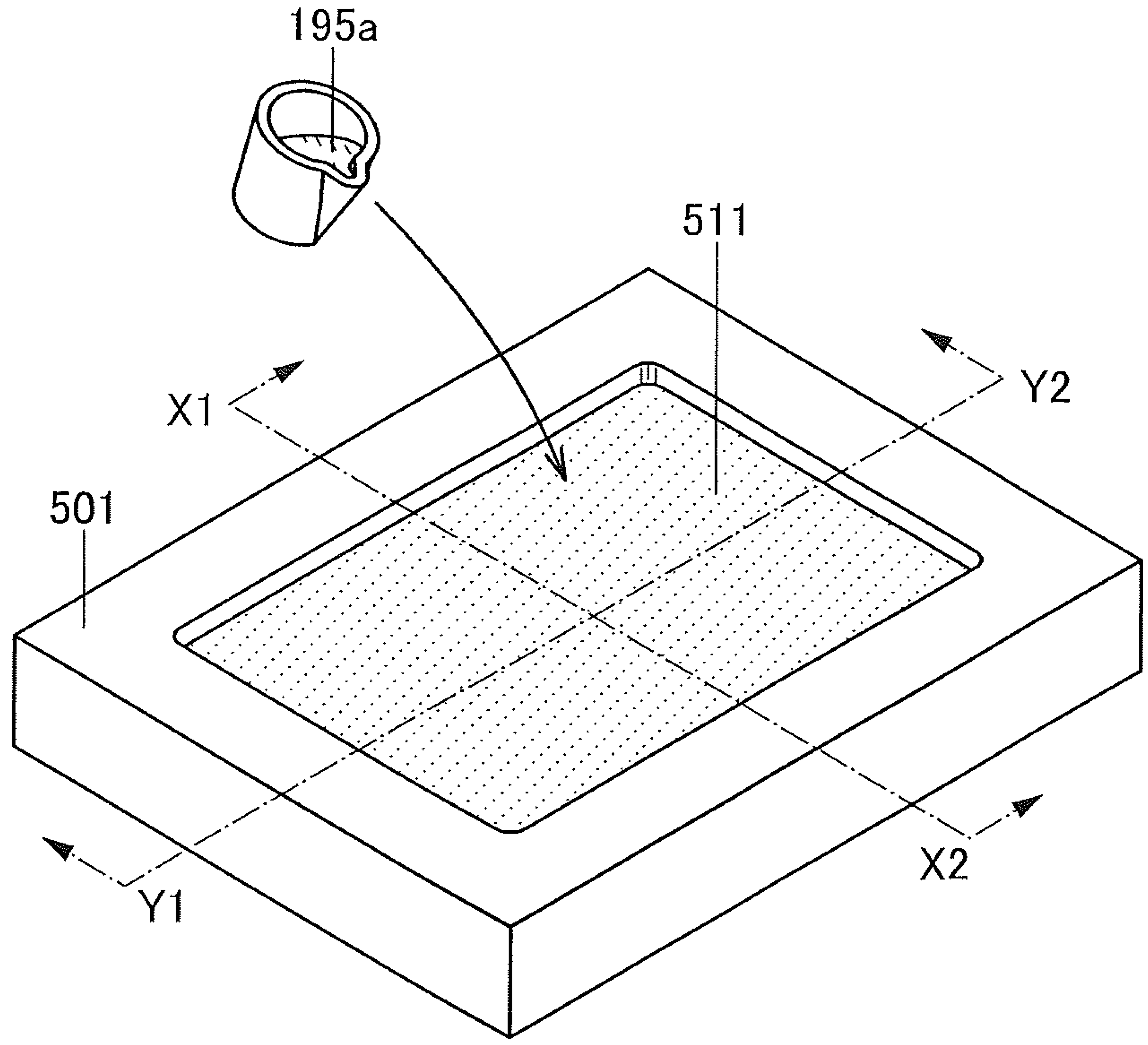


FIG. 32B

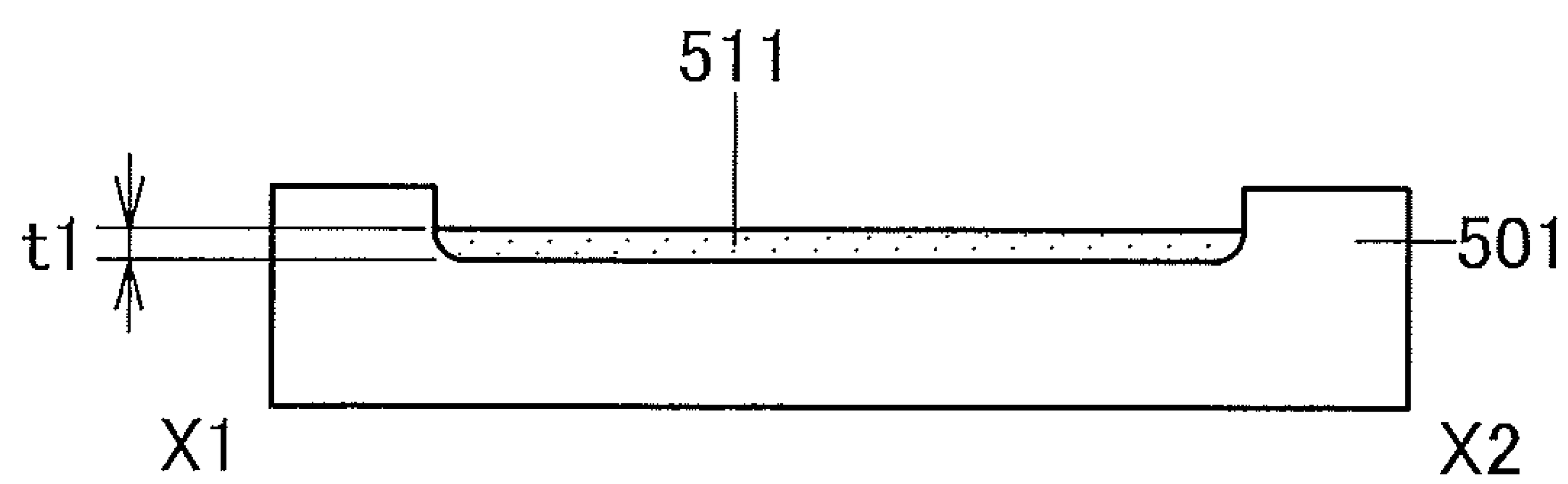


FIG. 32C

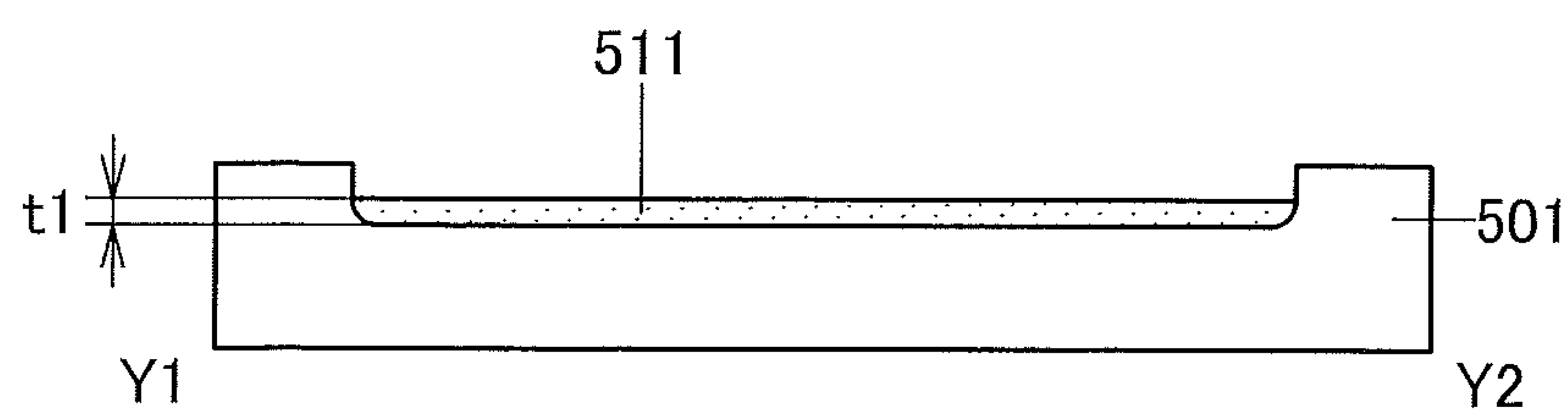


FIG. 33

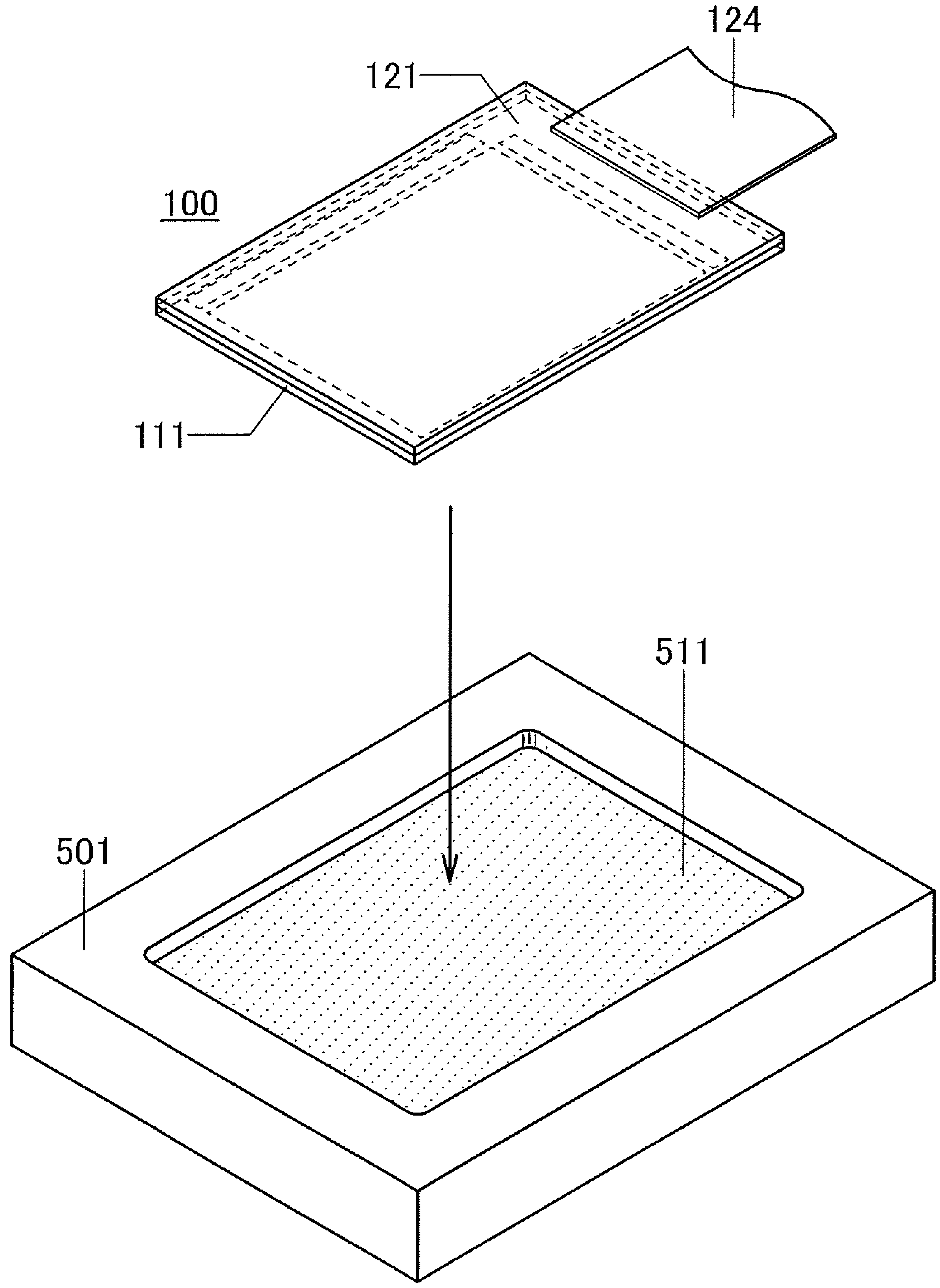


FIG. 34A

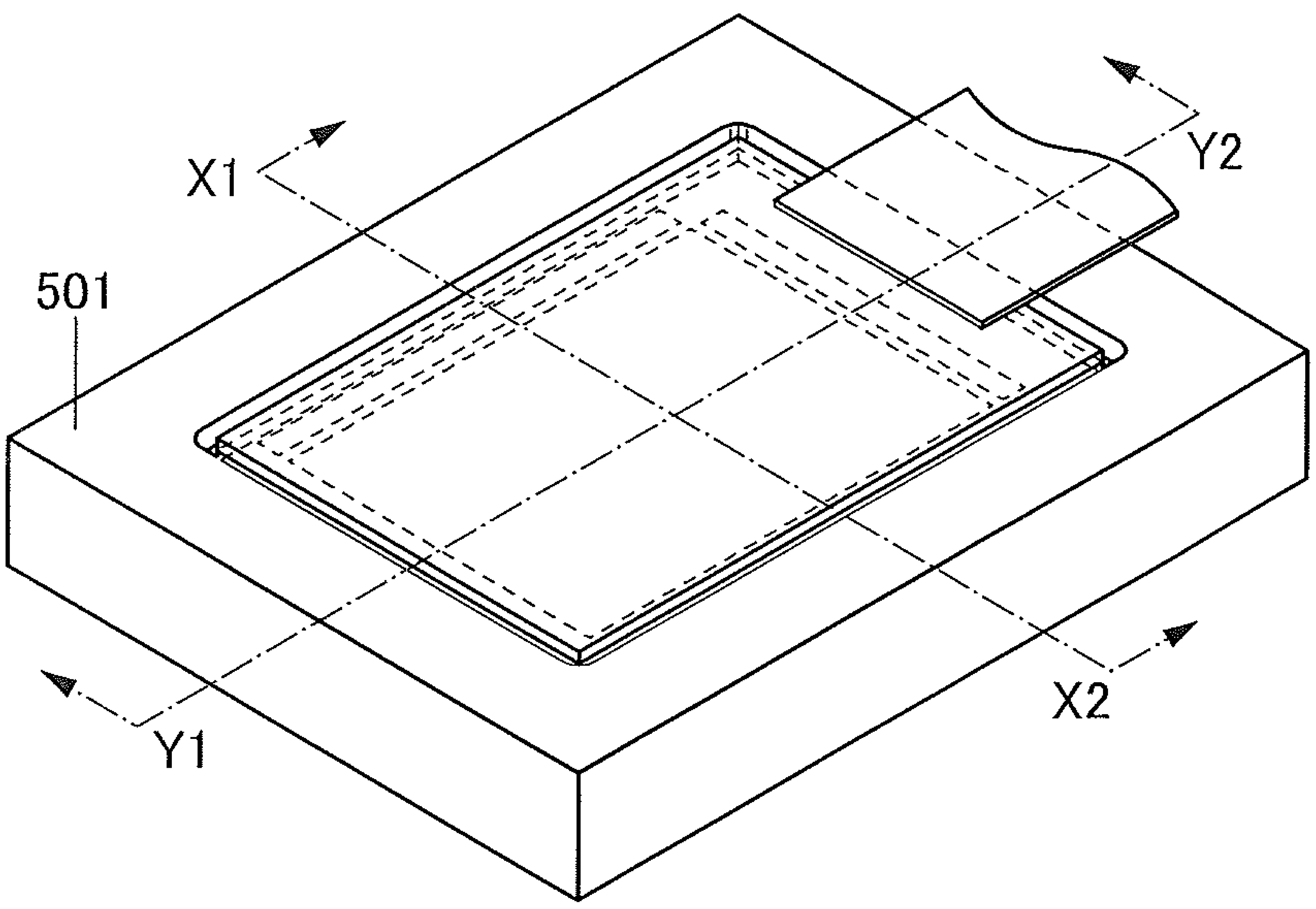


FIG. 34B

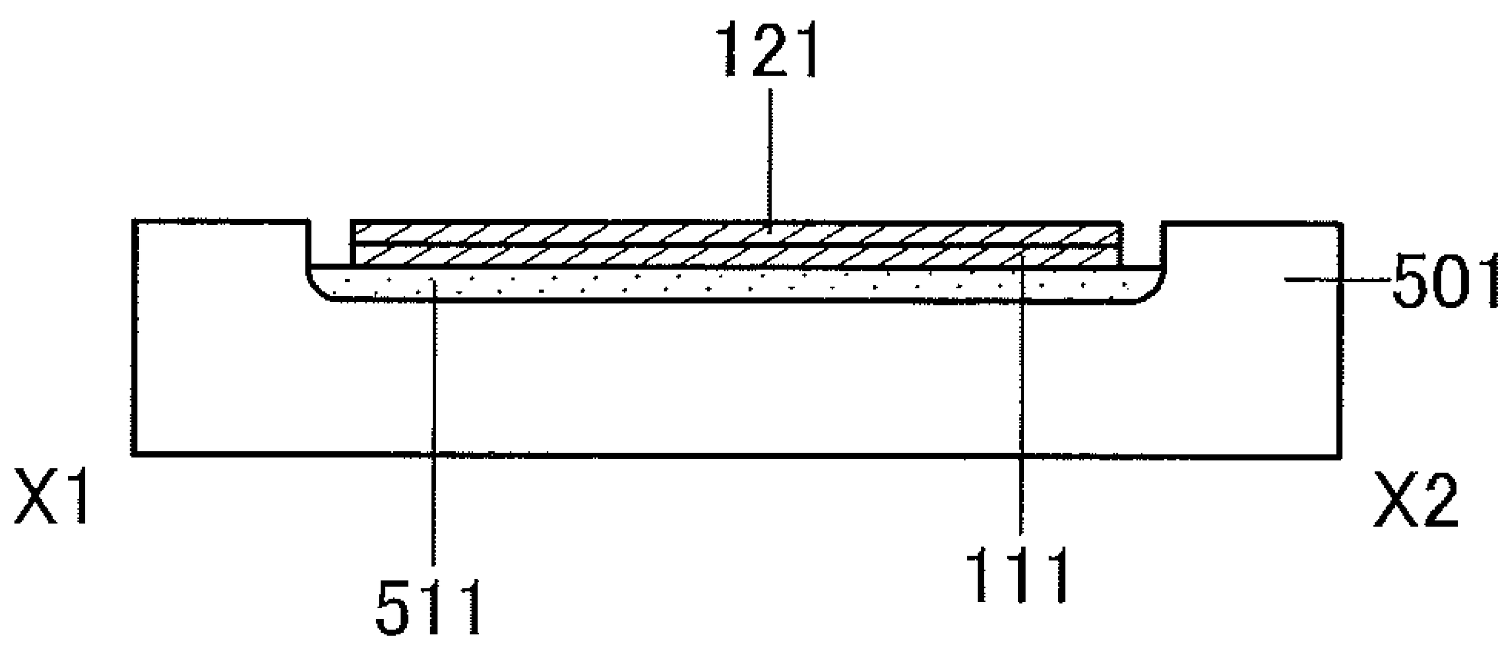


FIG. 34C

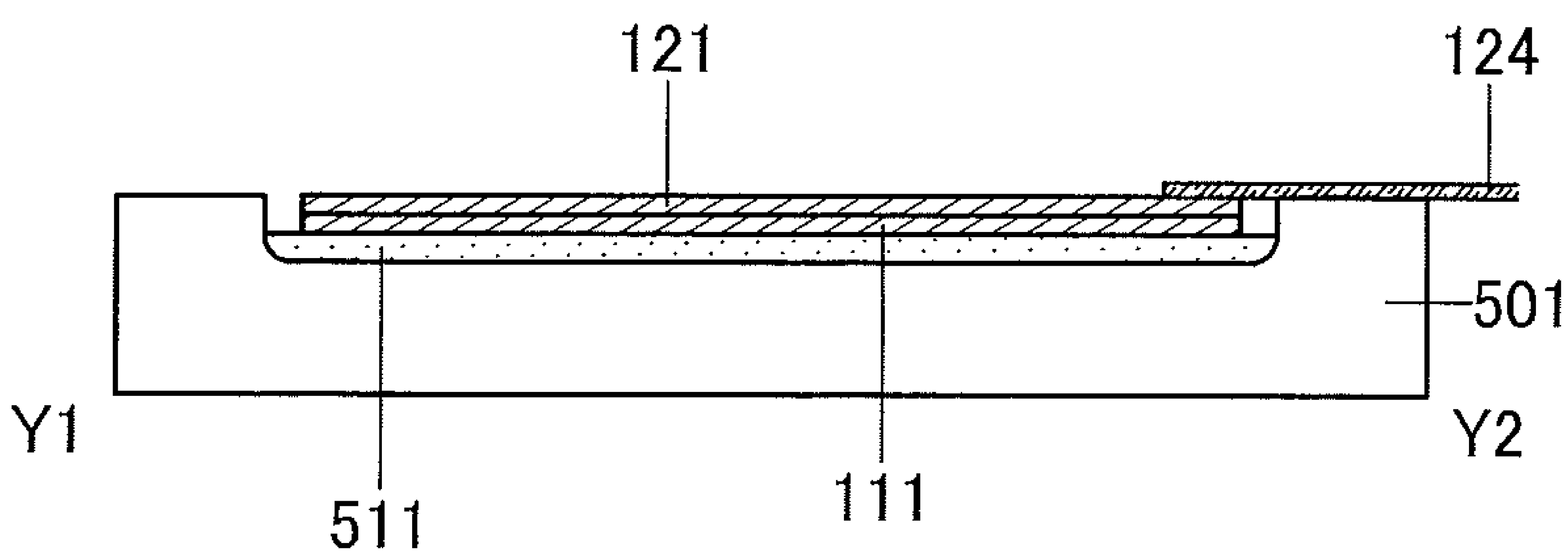


FIG. 35A

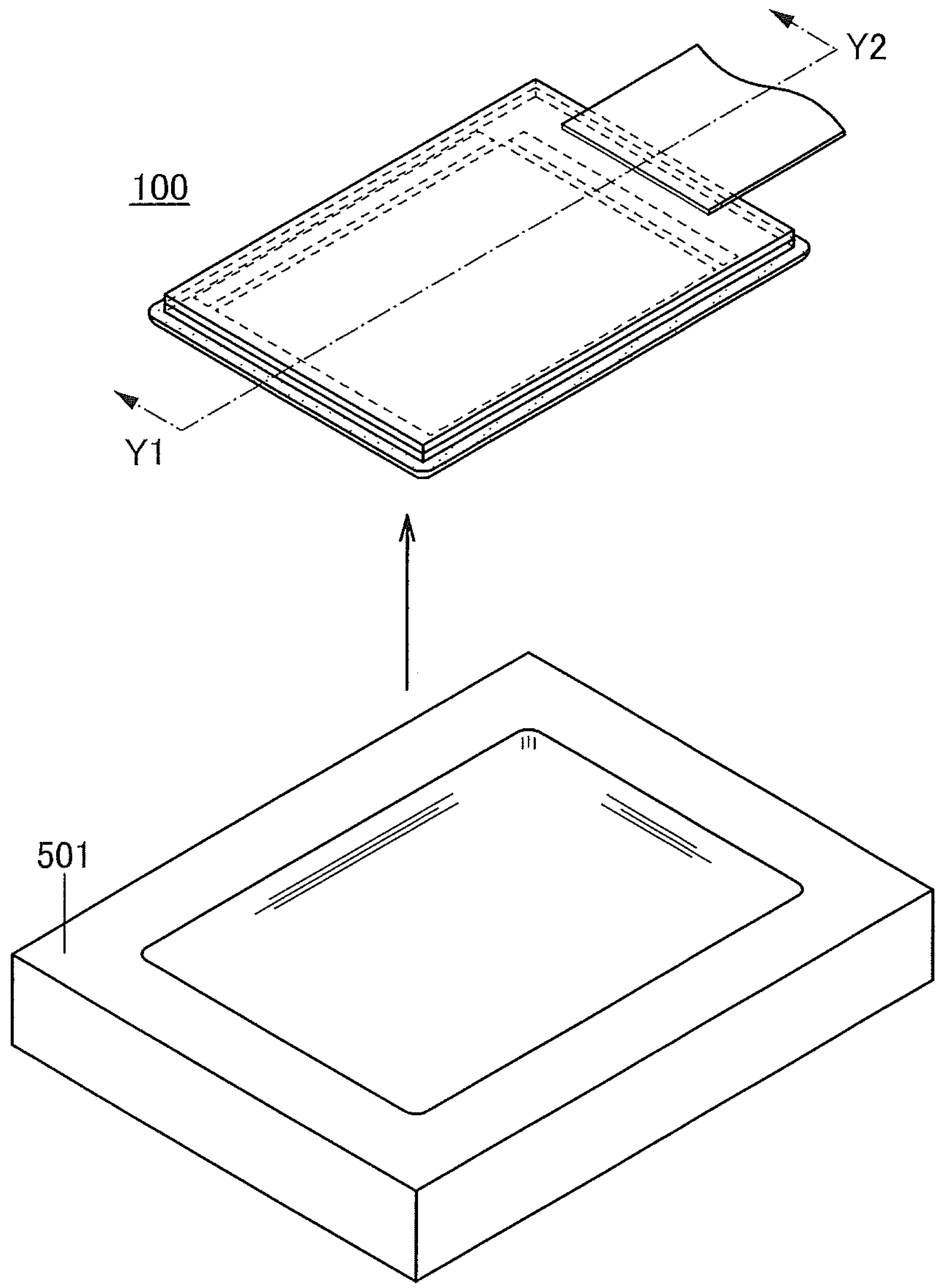


FIG. 35B

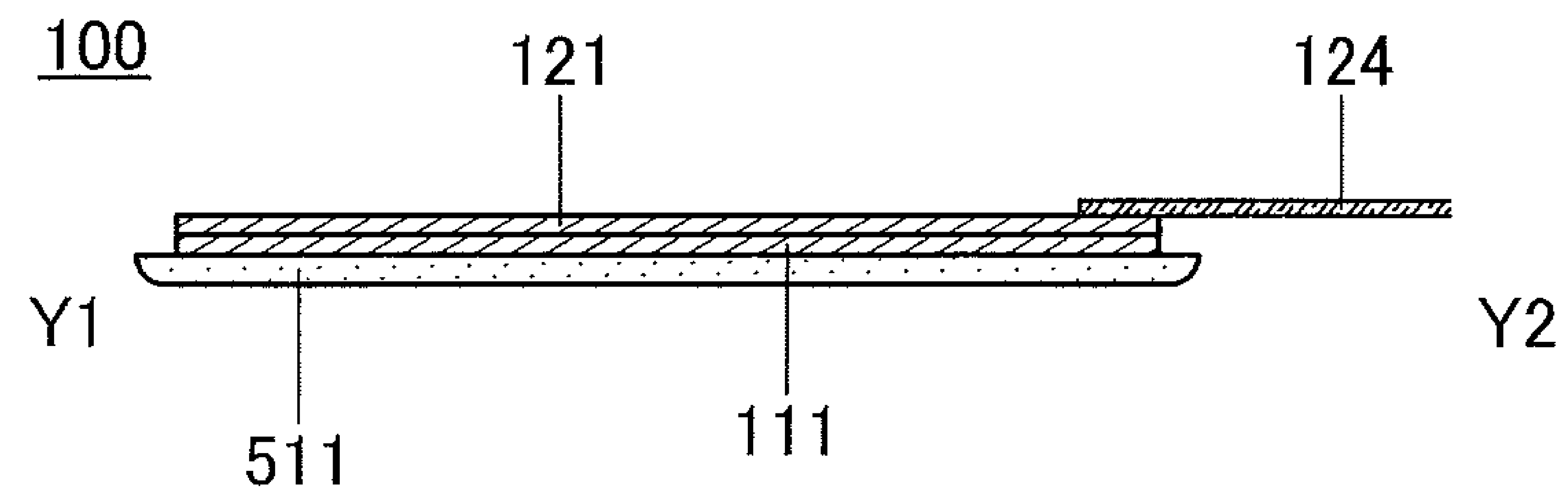


FIG. 36

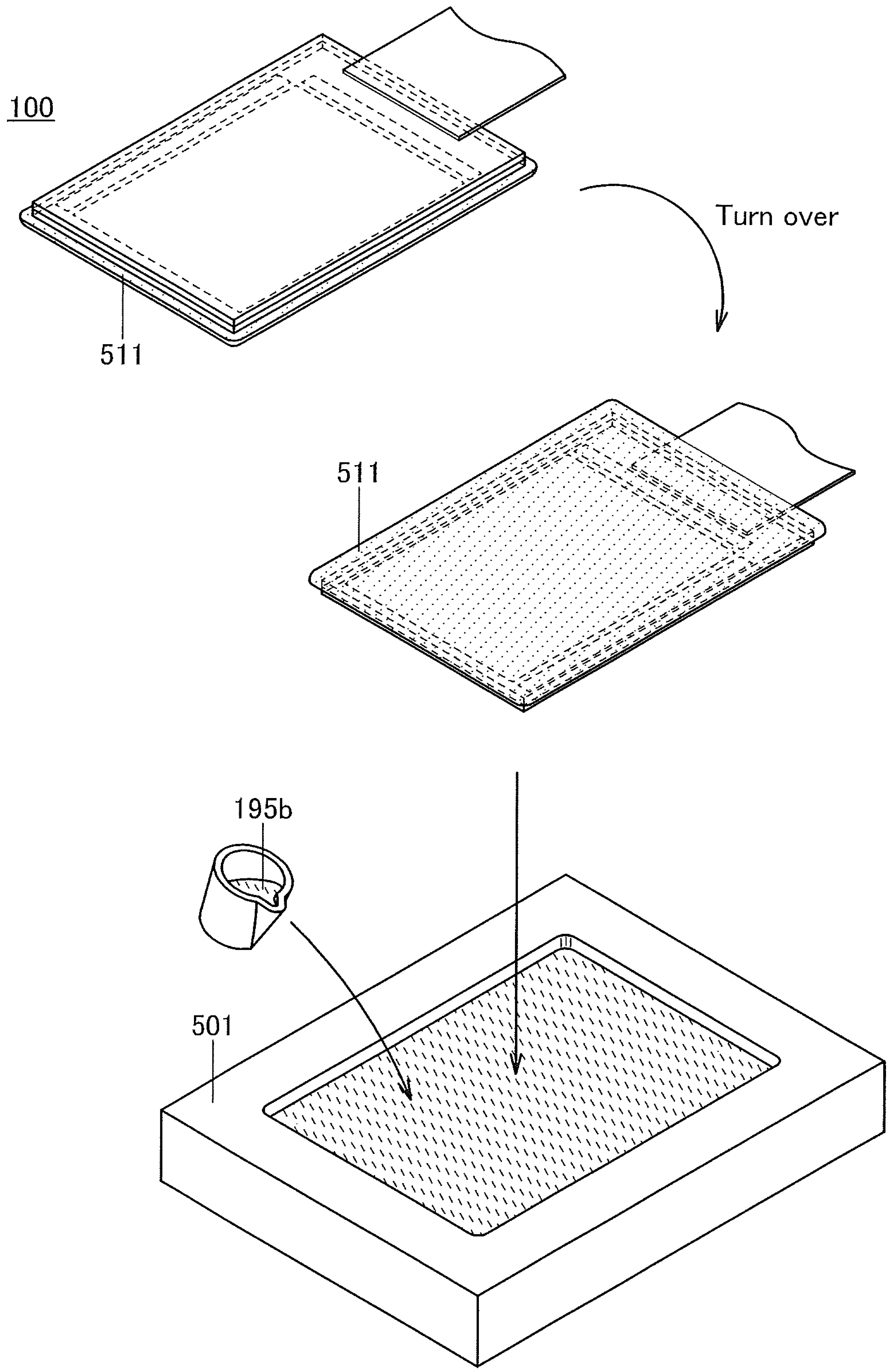


FIG. 37A

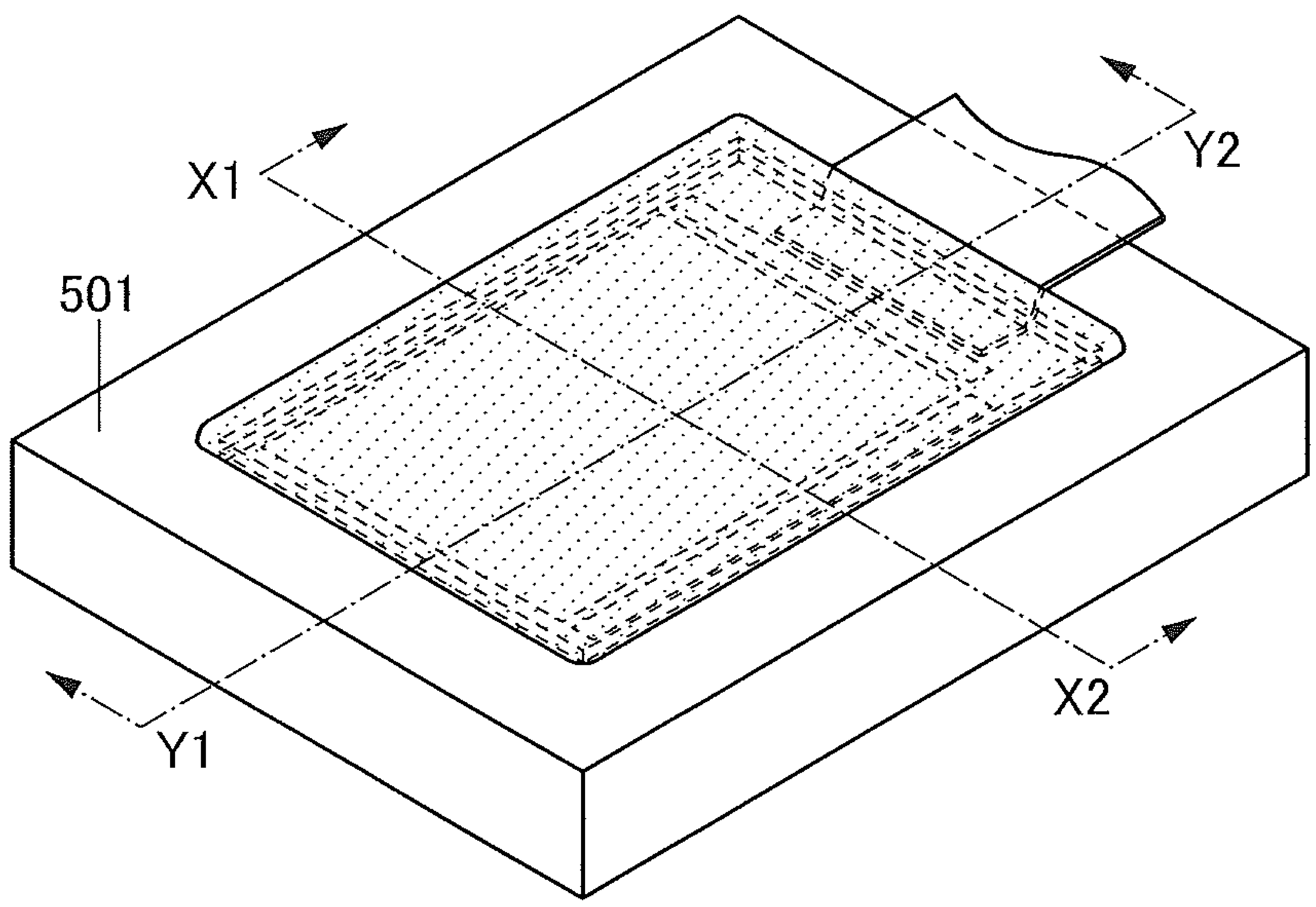


FIG. 37B

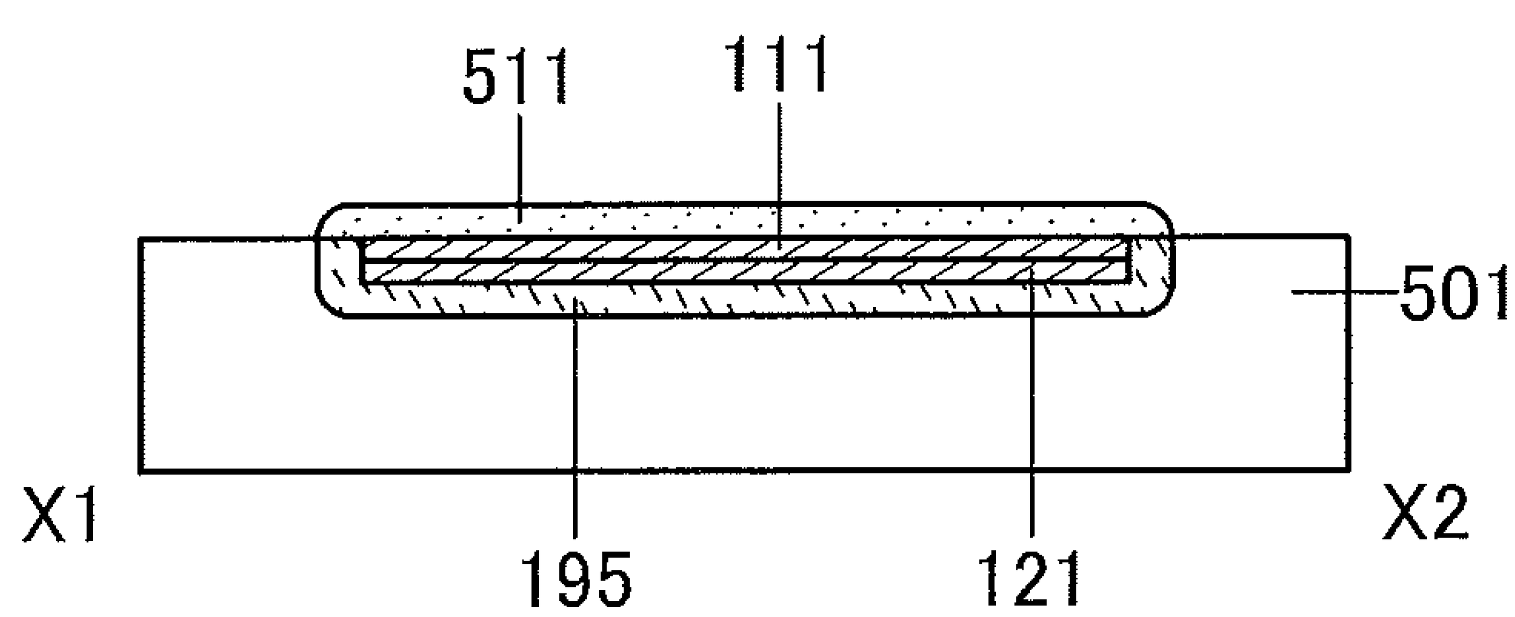


FIG. 37C

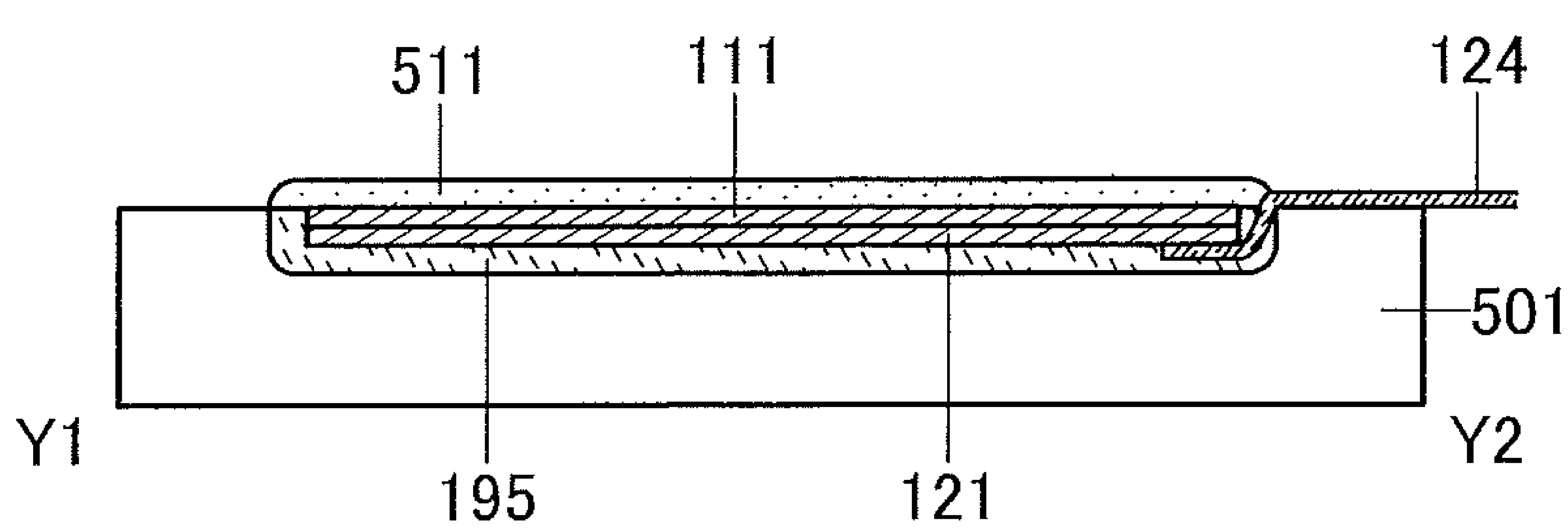


FIG. 38A

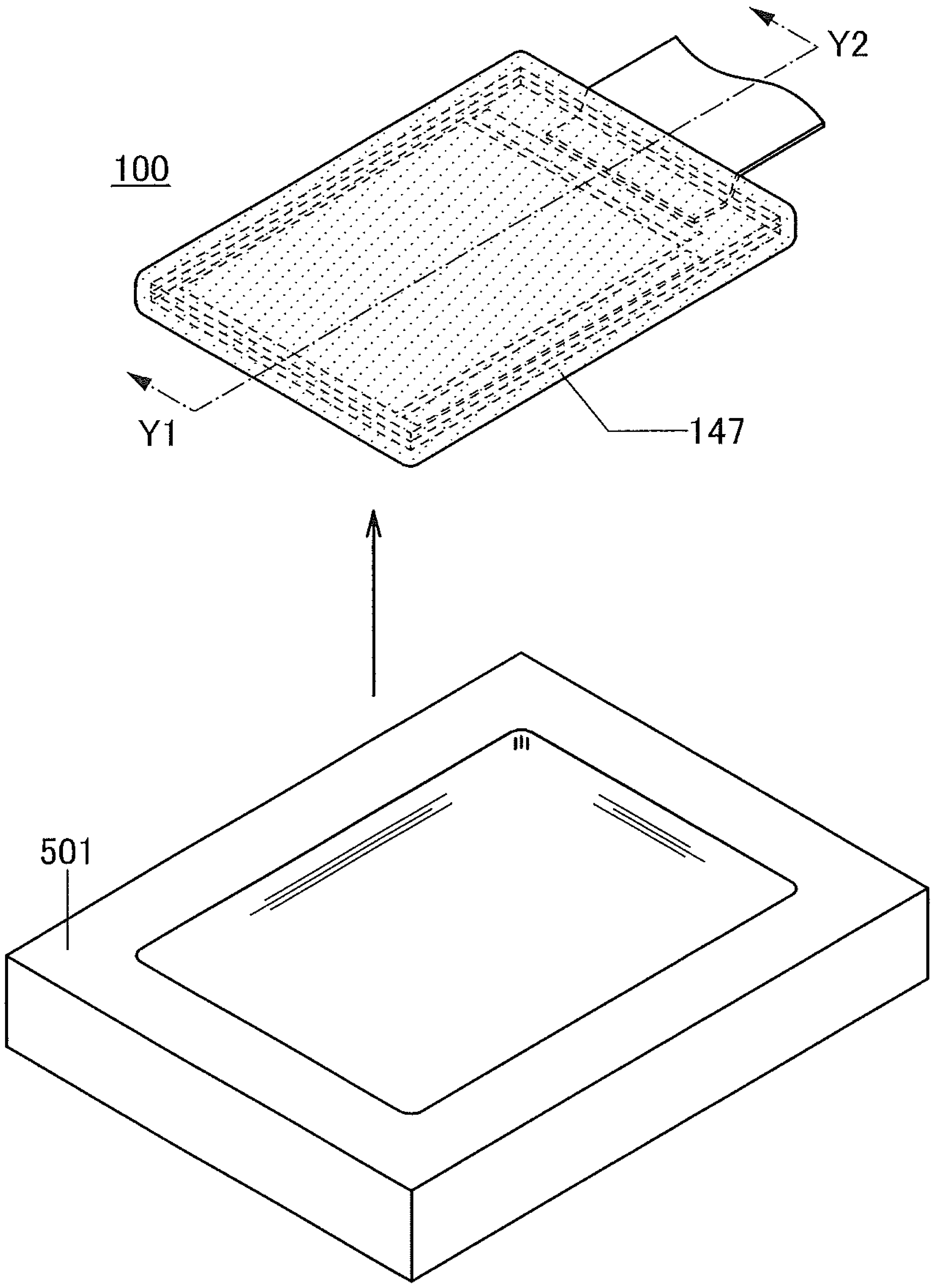


FIG. 38B

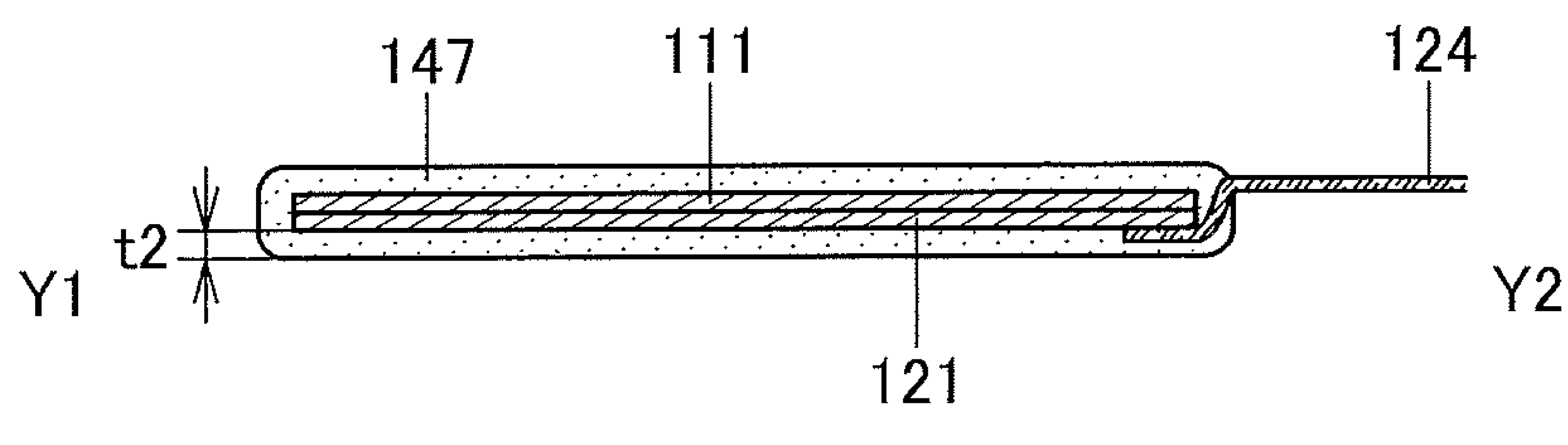


FIG. 39A

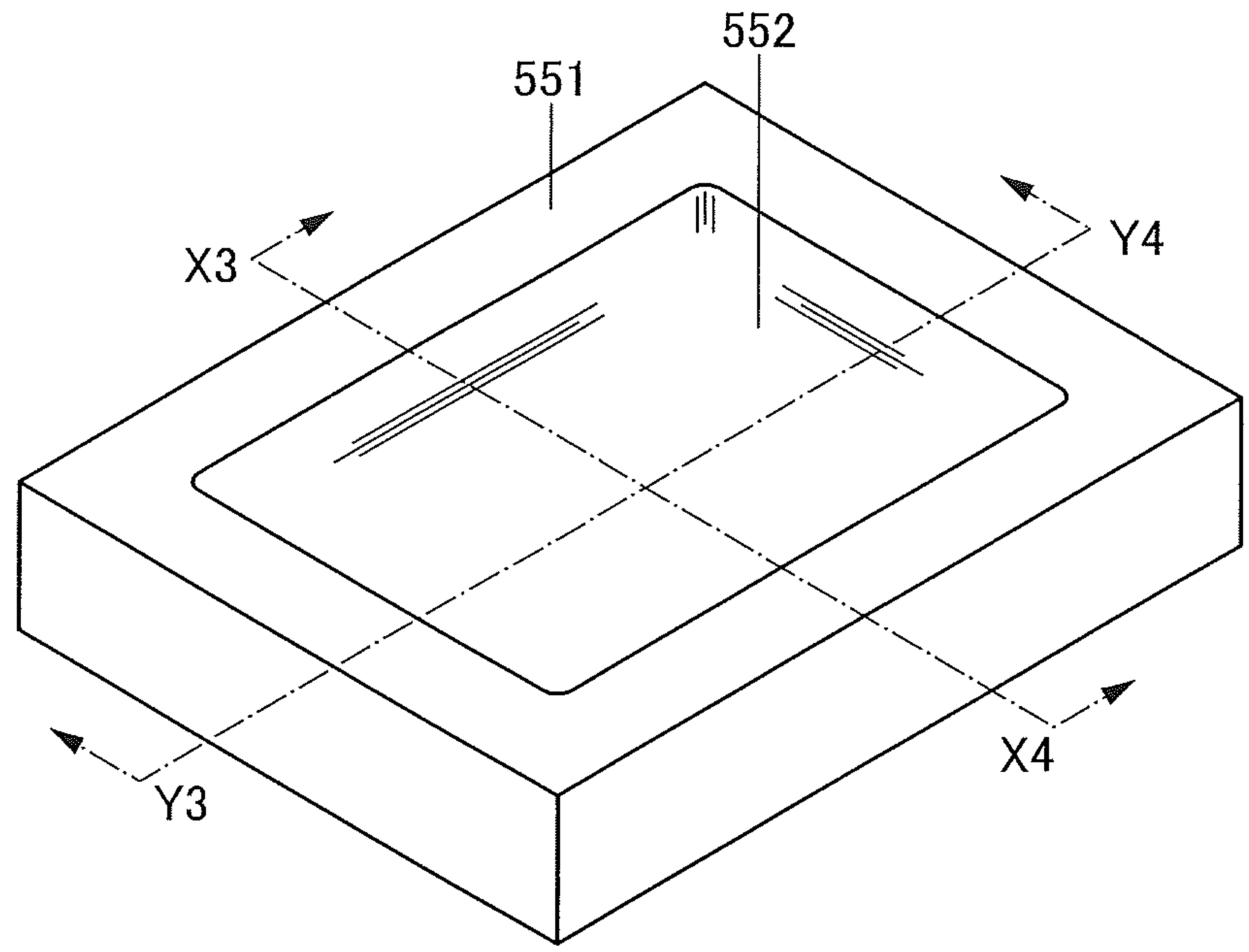


FIG. 39B

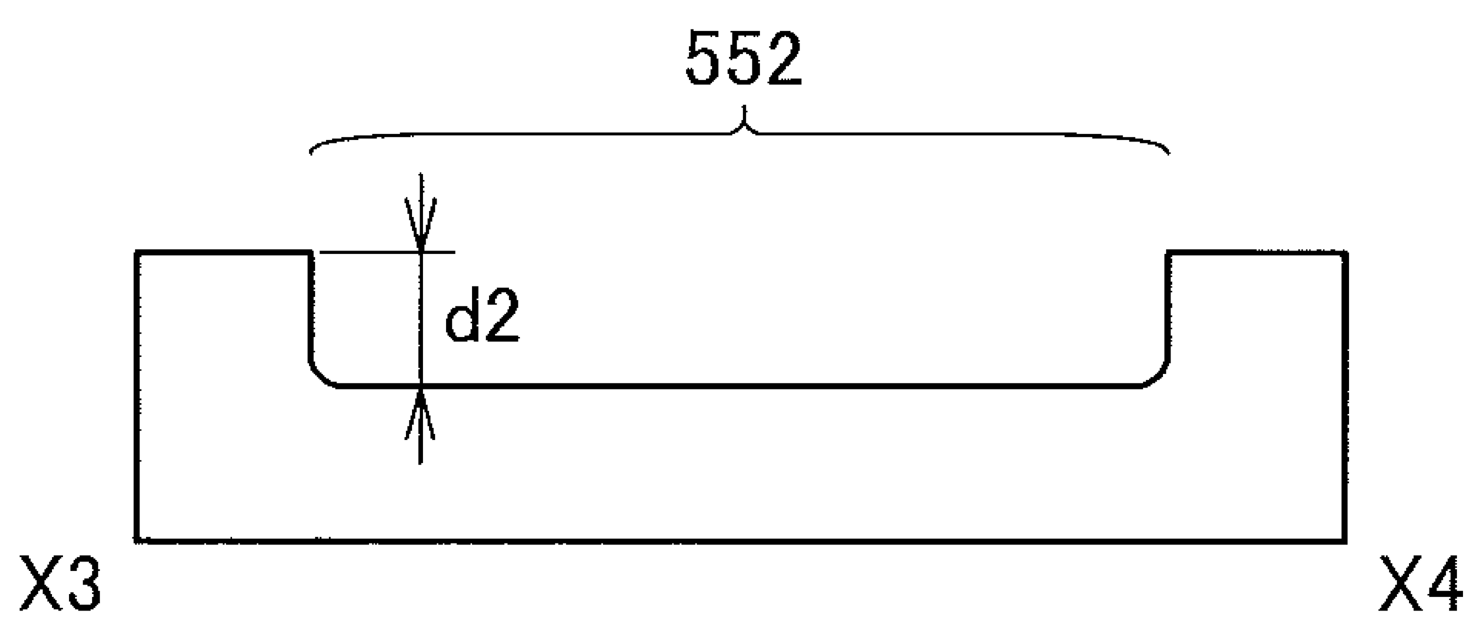


FIG. 39C

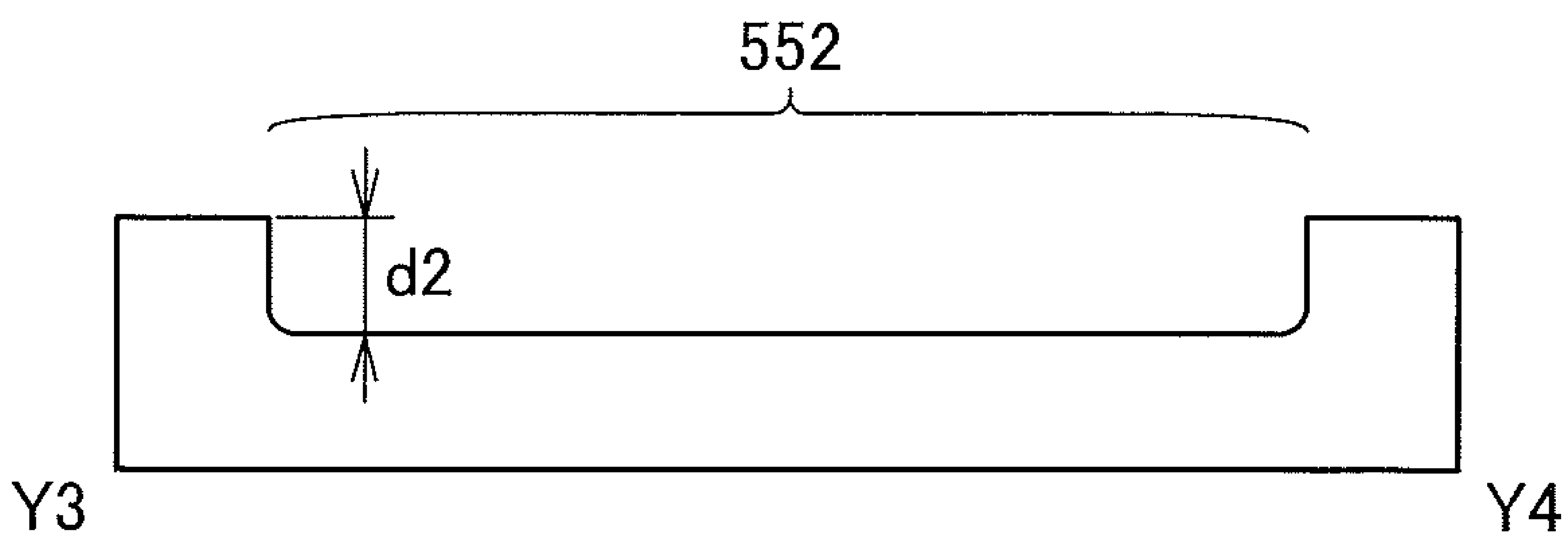


FIG. 40A

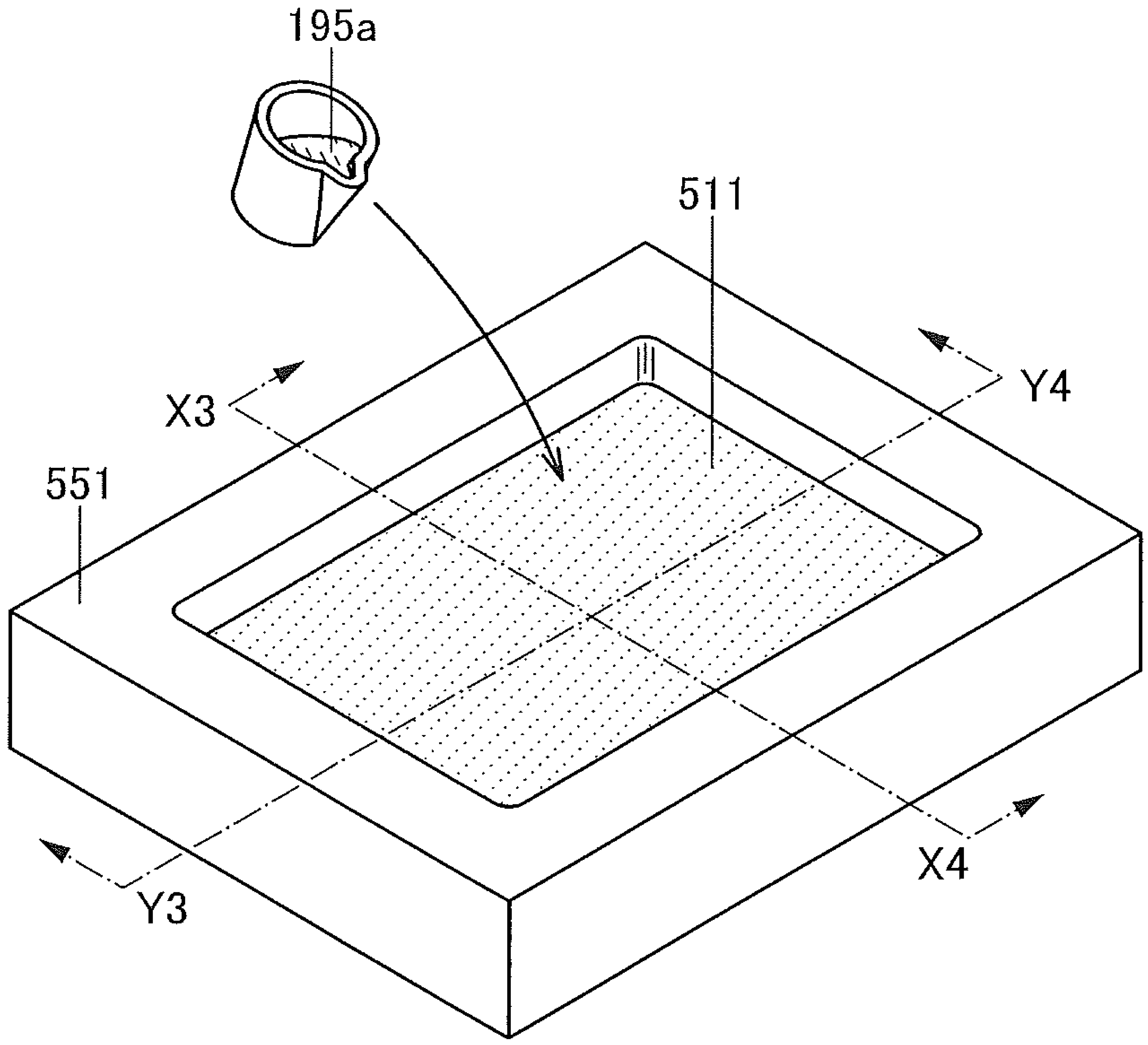


FIG. 40B

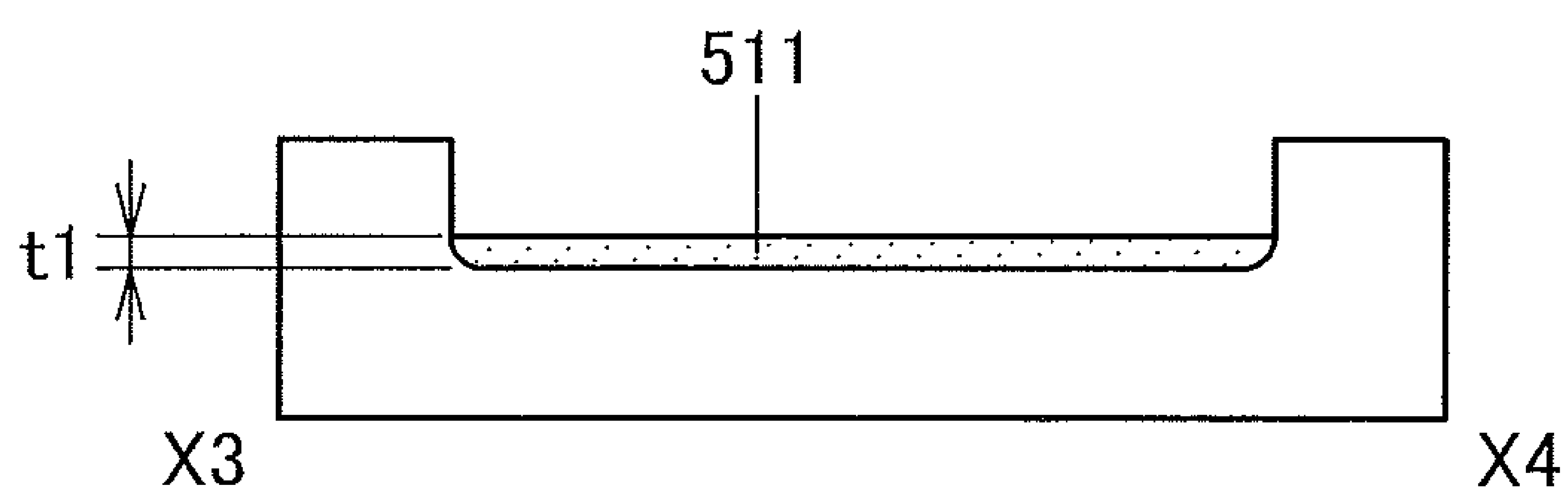


FIG. 40C

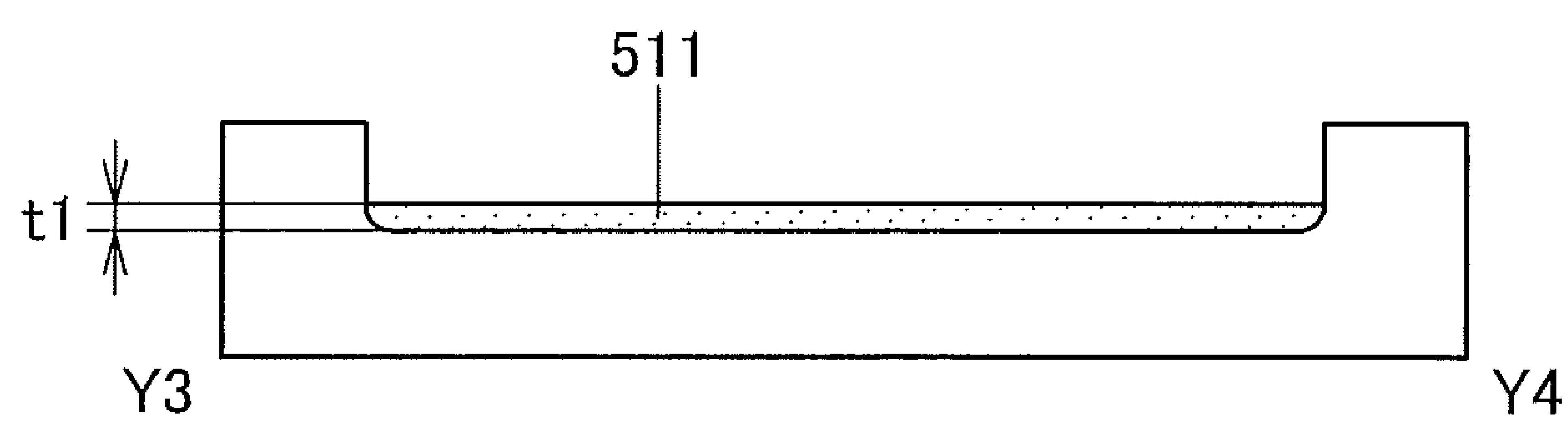


FIG. 41

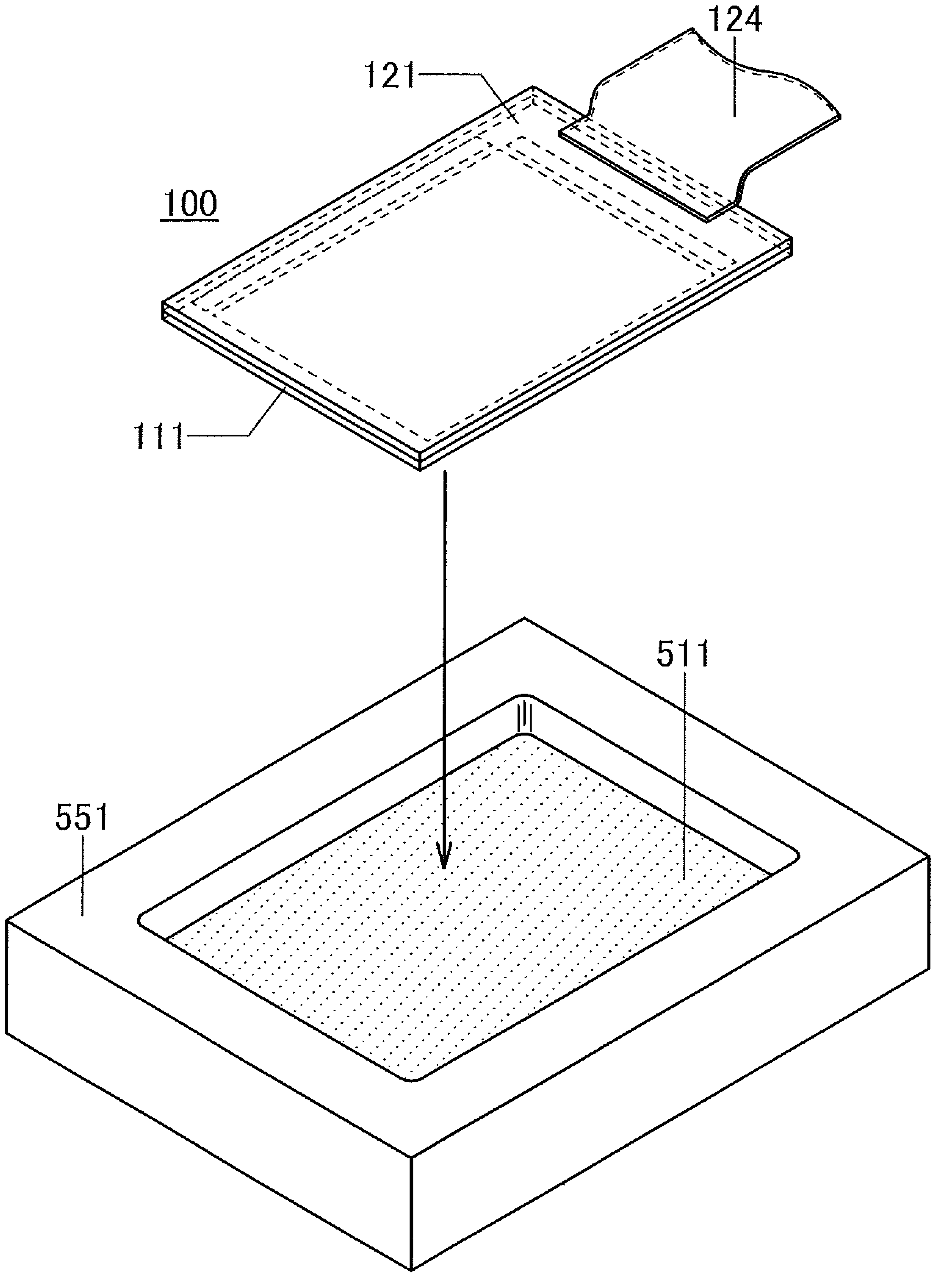


FIG. 42A

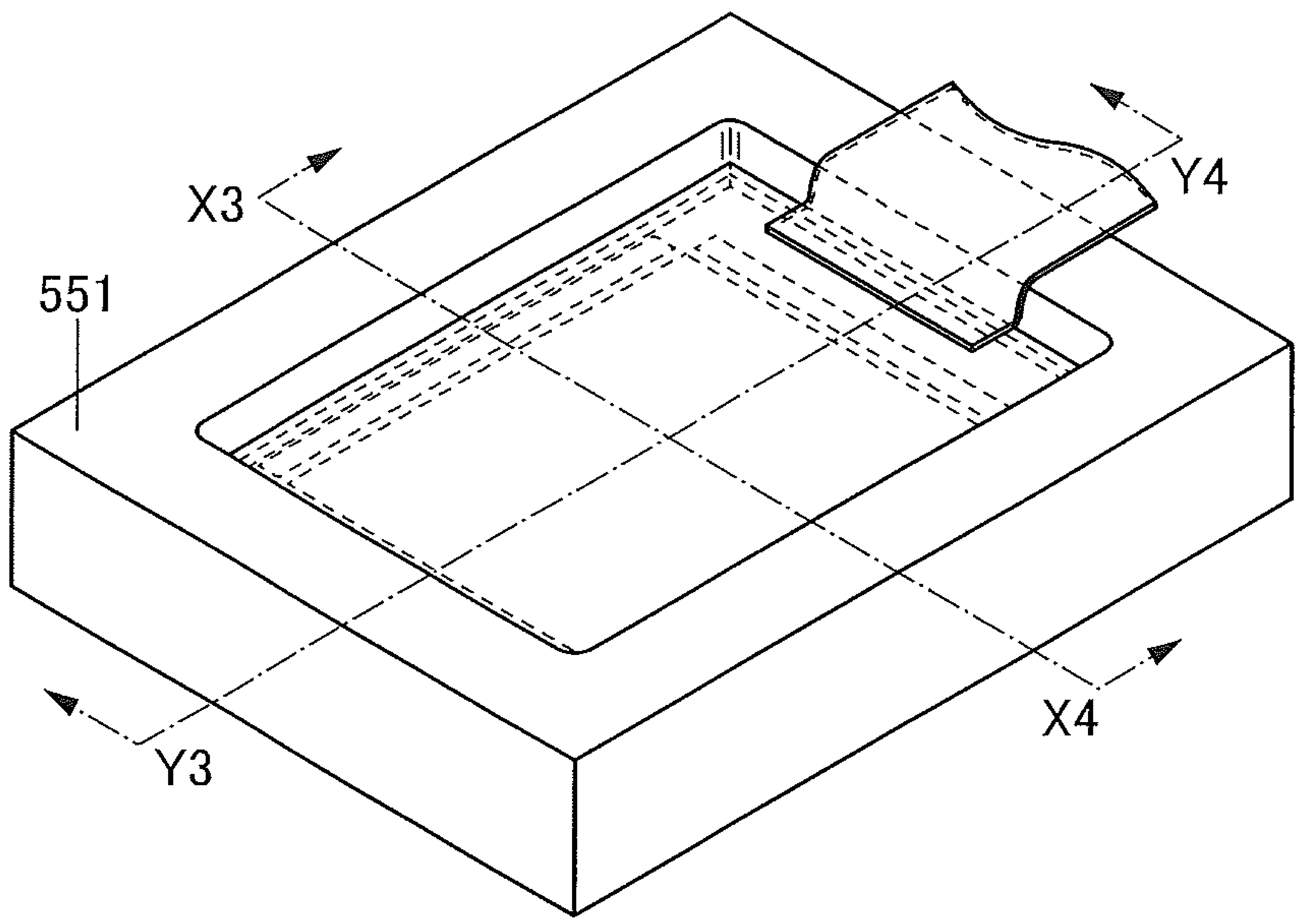


FIG. 42B

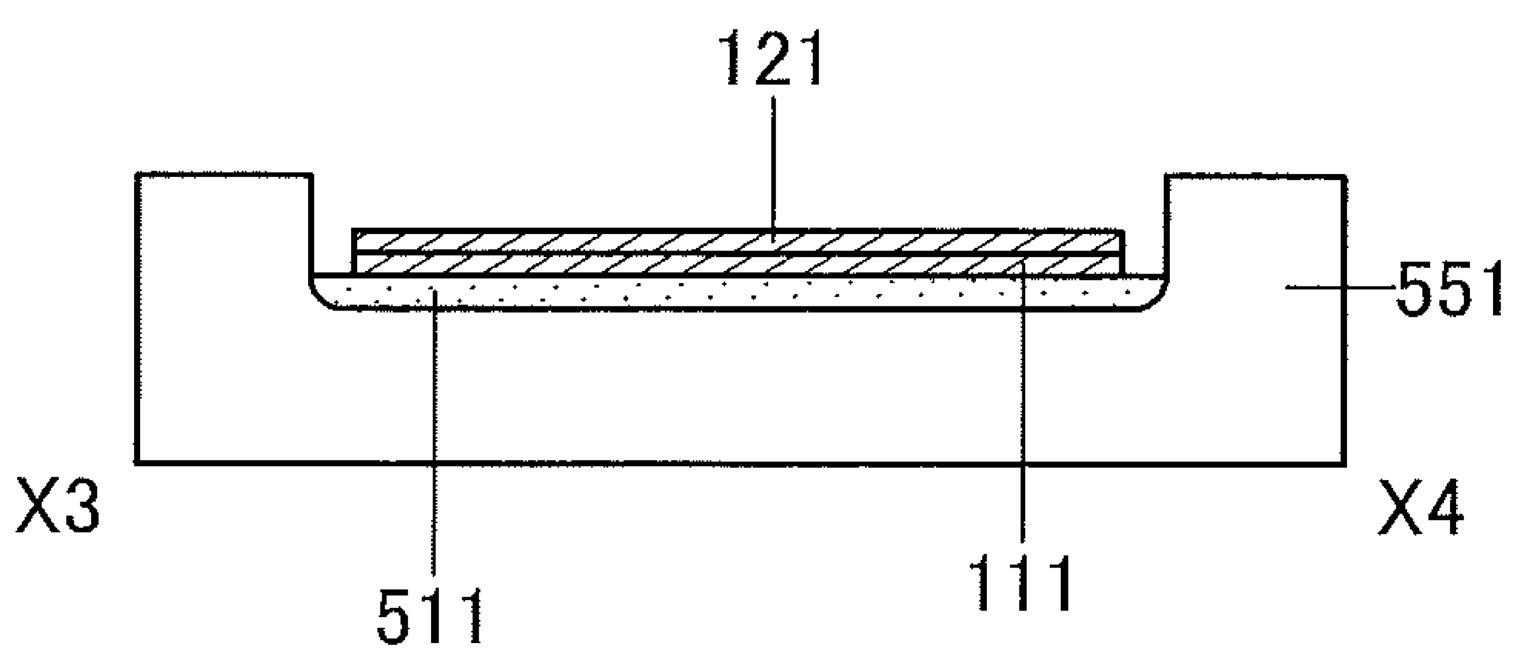


FIG. 42C

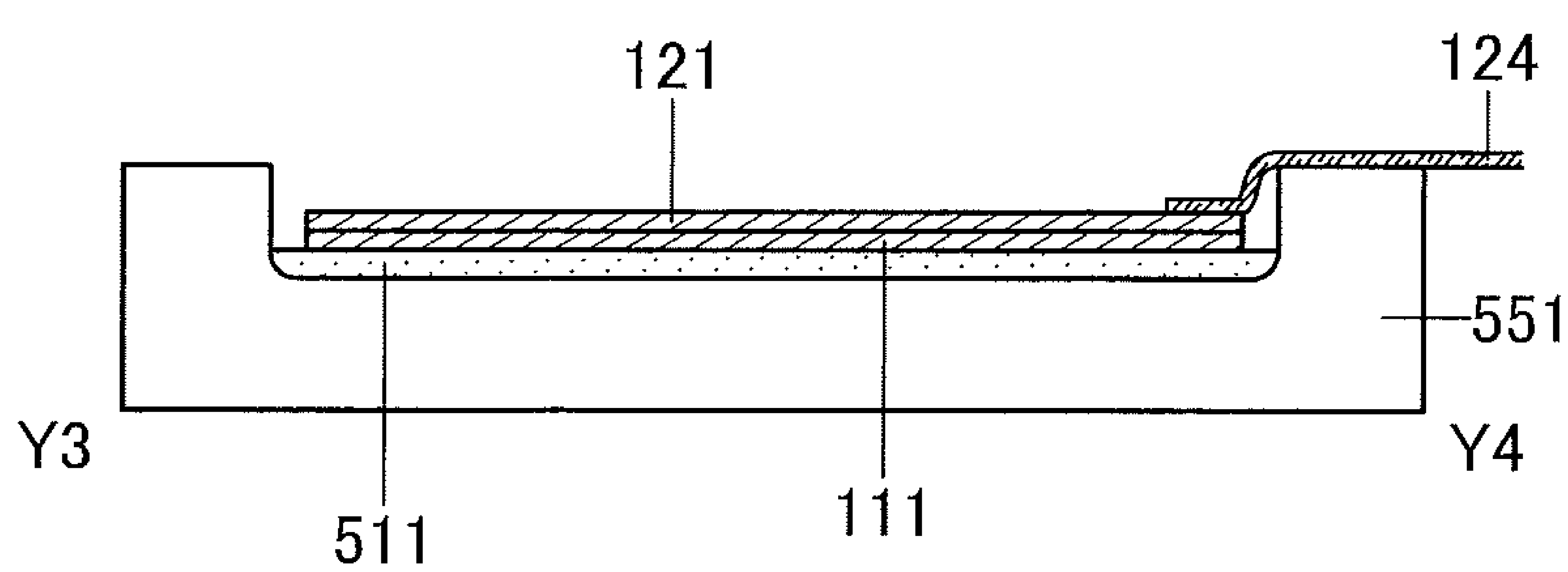


FIG. 43A

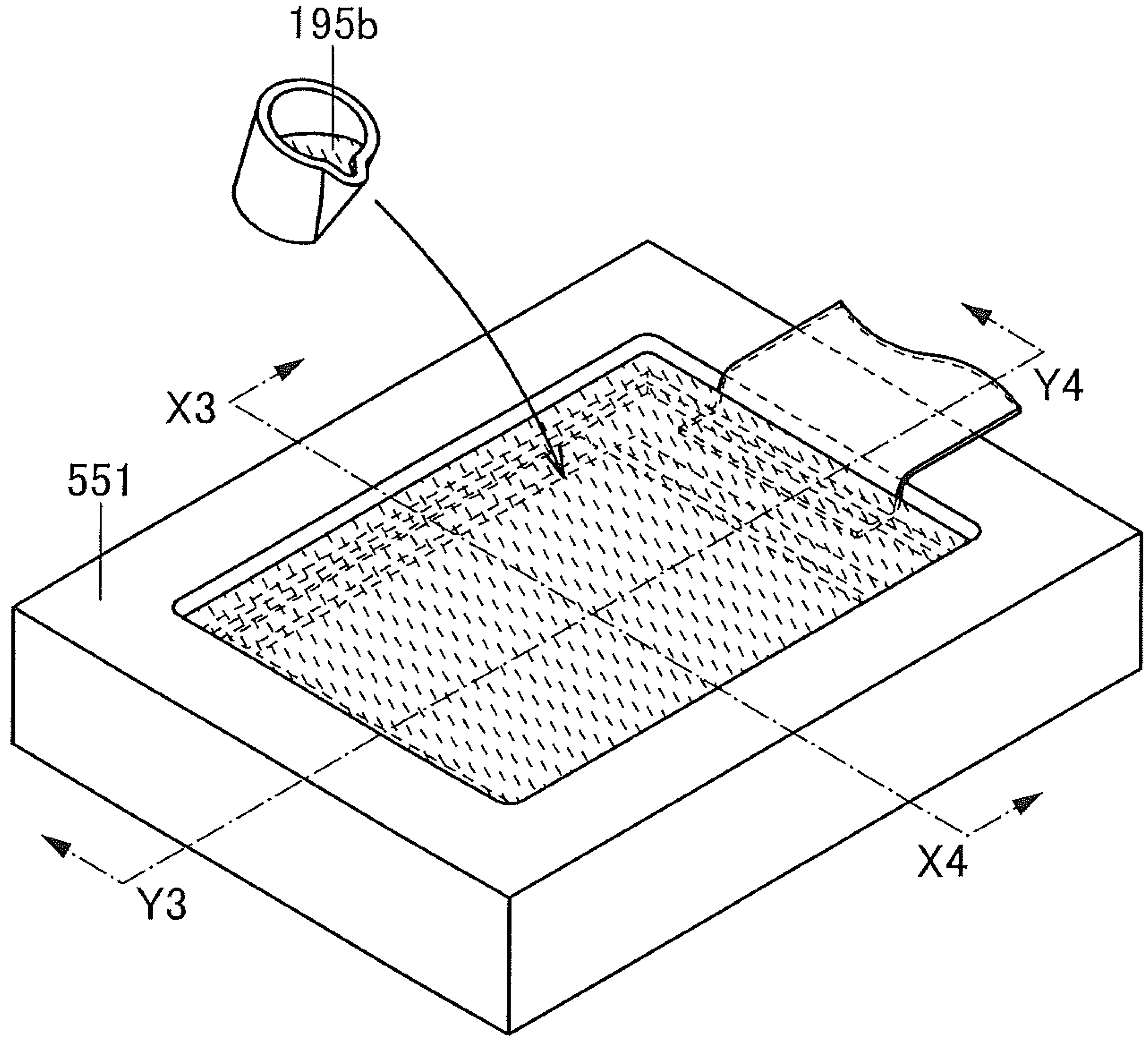


FIG. 43B

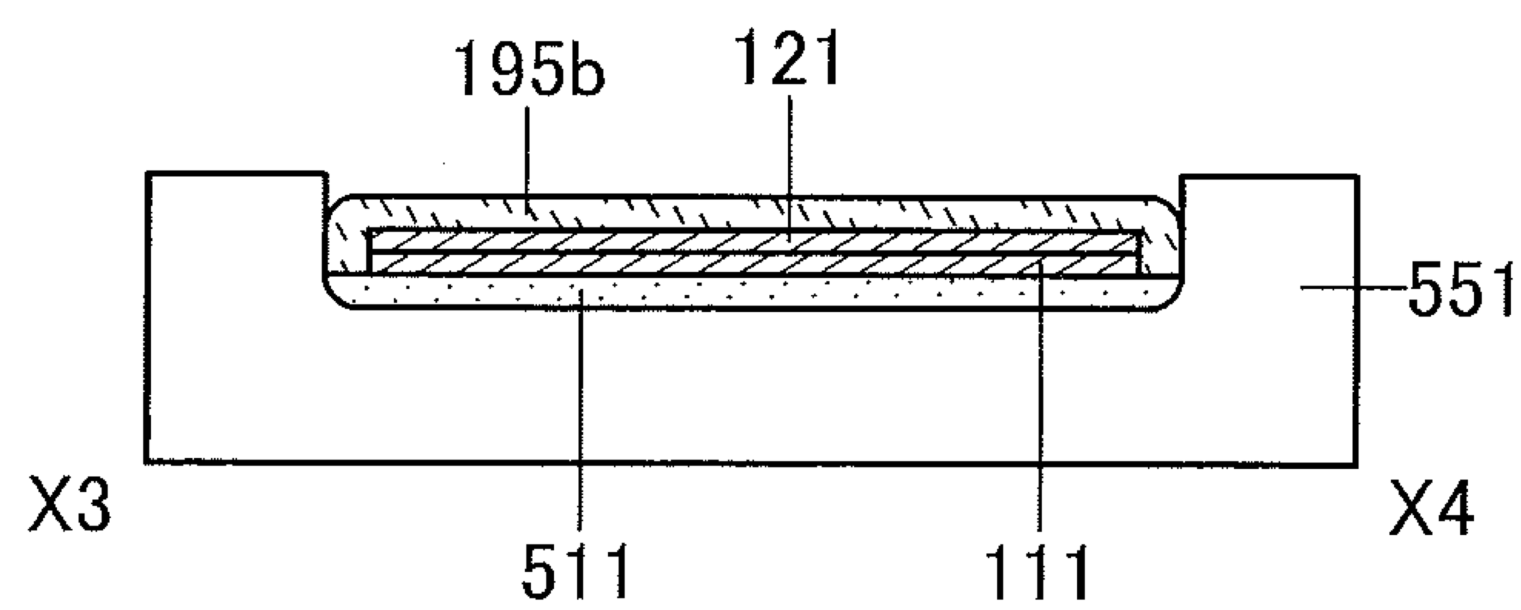


FIG. 43C

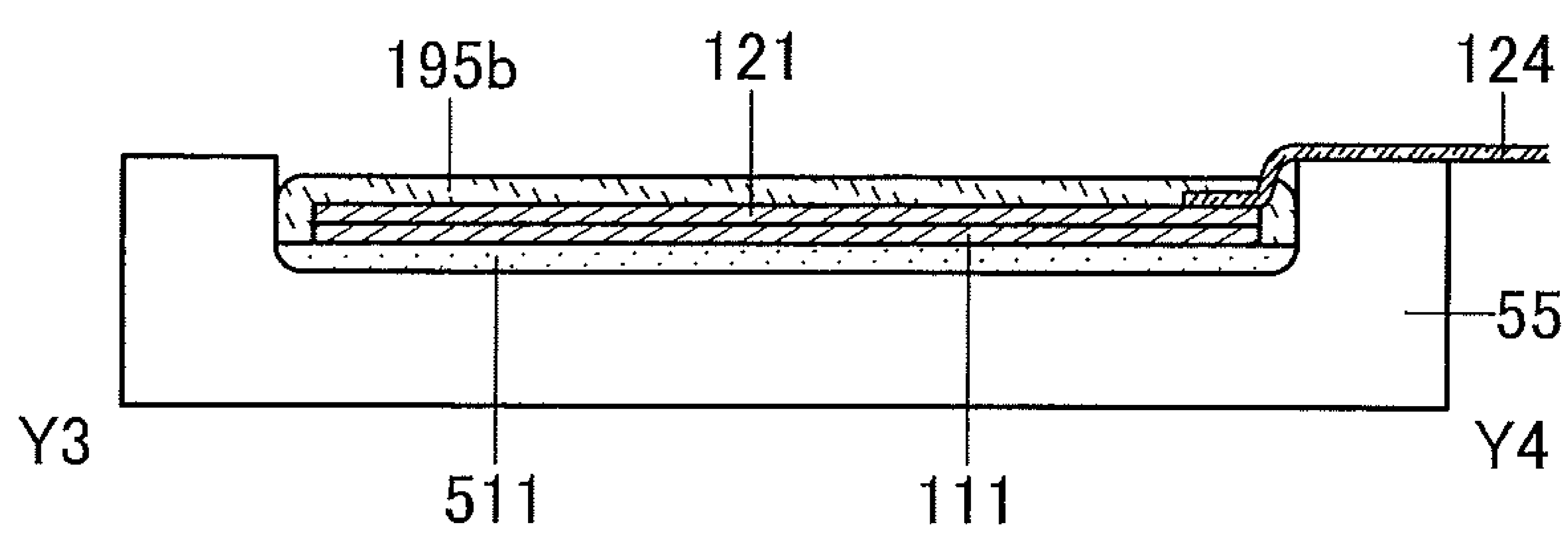


FIG. 44A

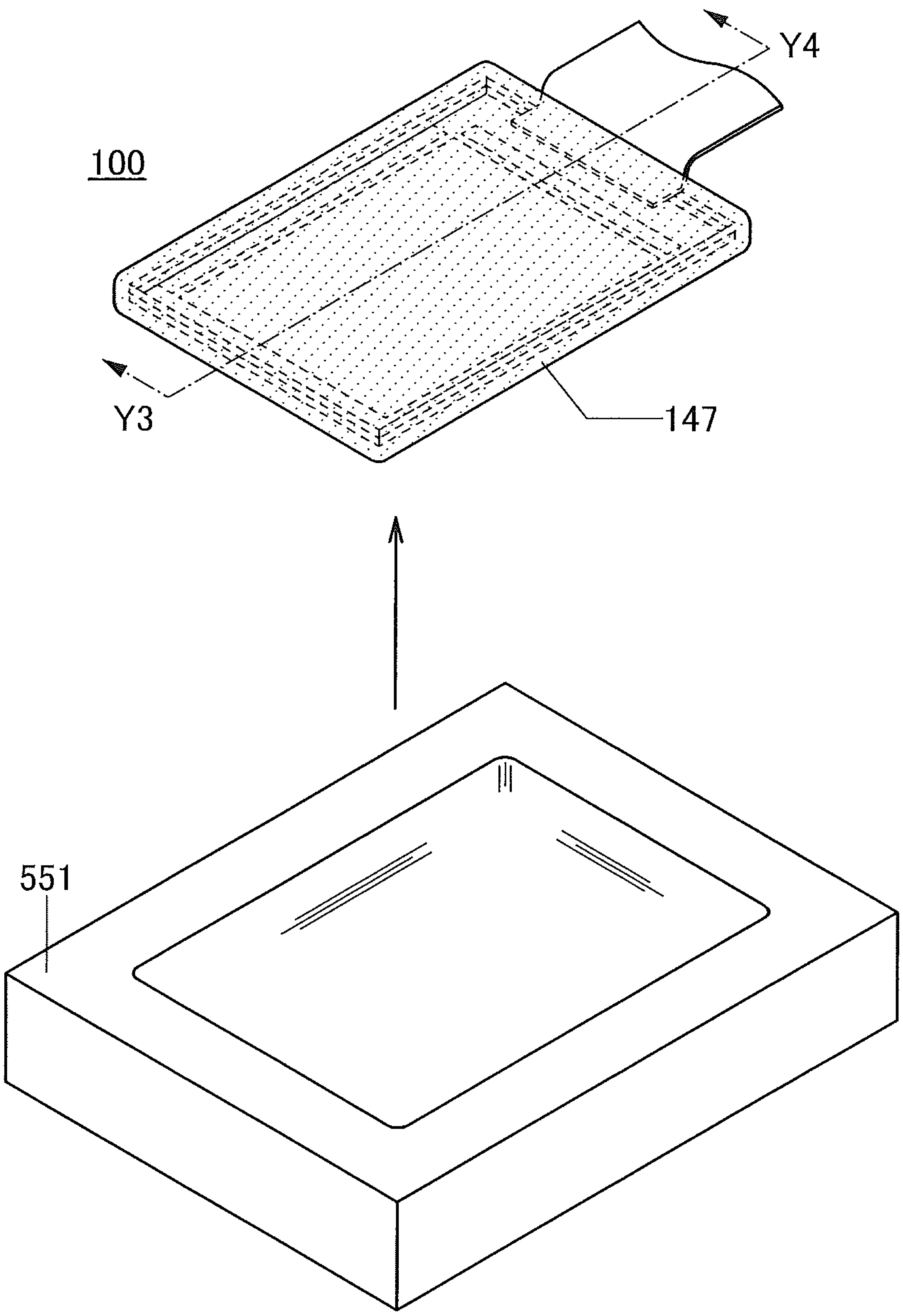


FIG. 44B

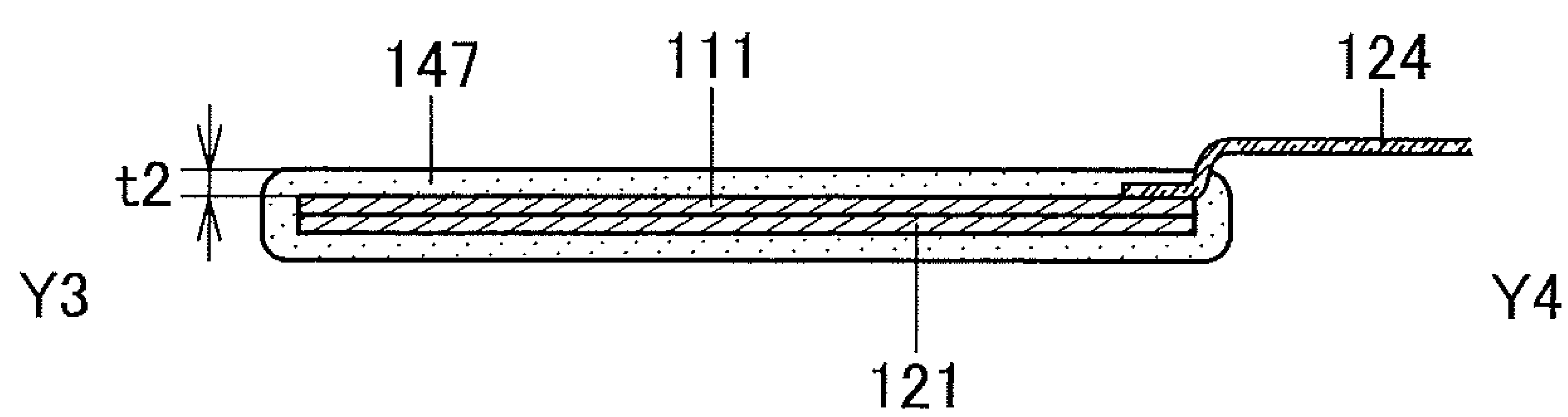


FIG. 45A1

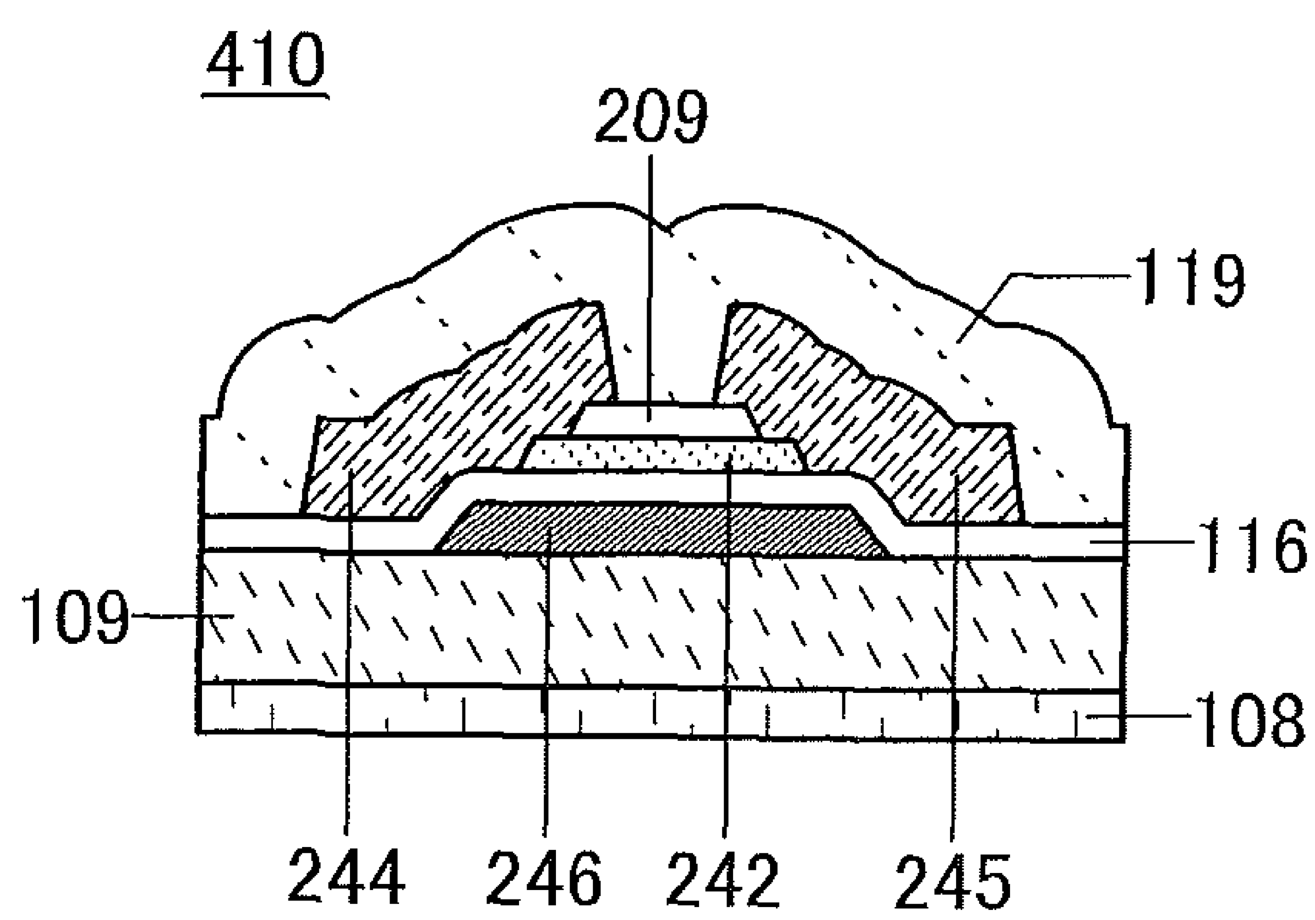


FIG. 45A2

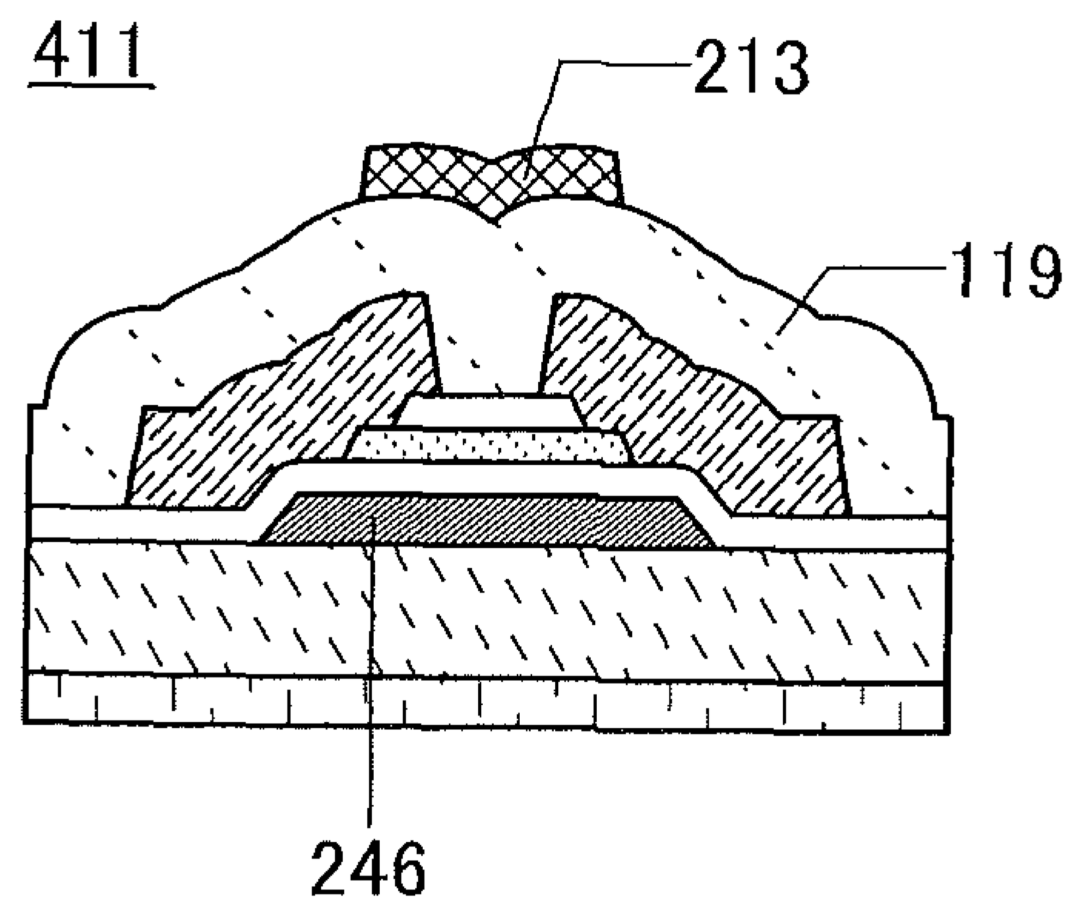


FIG. 45B1

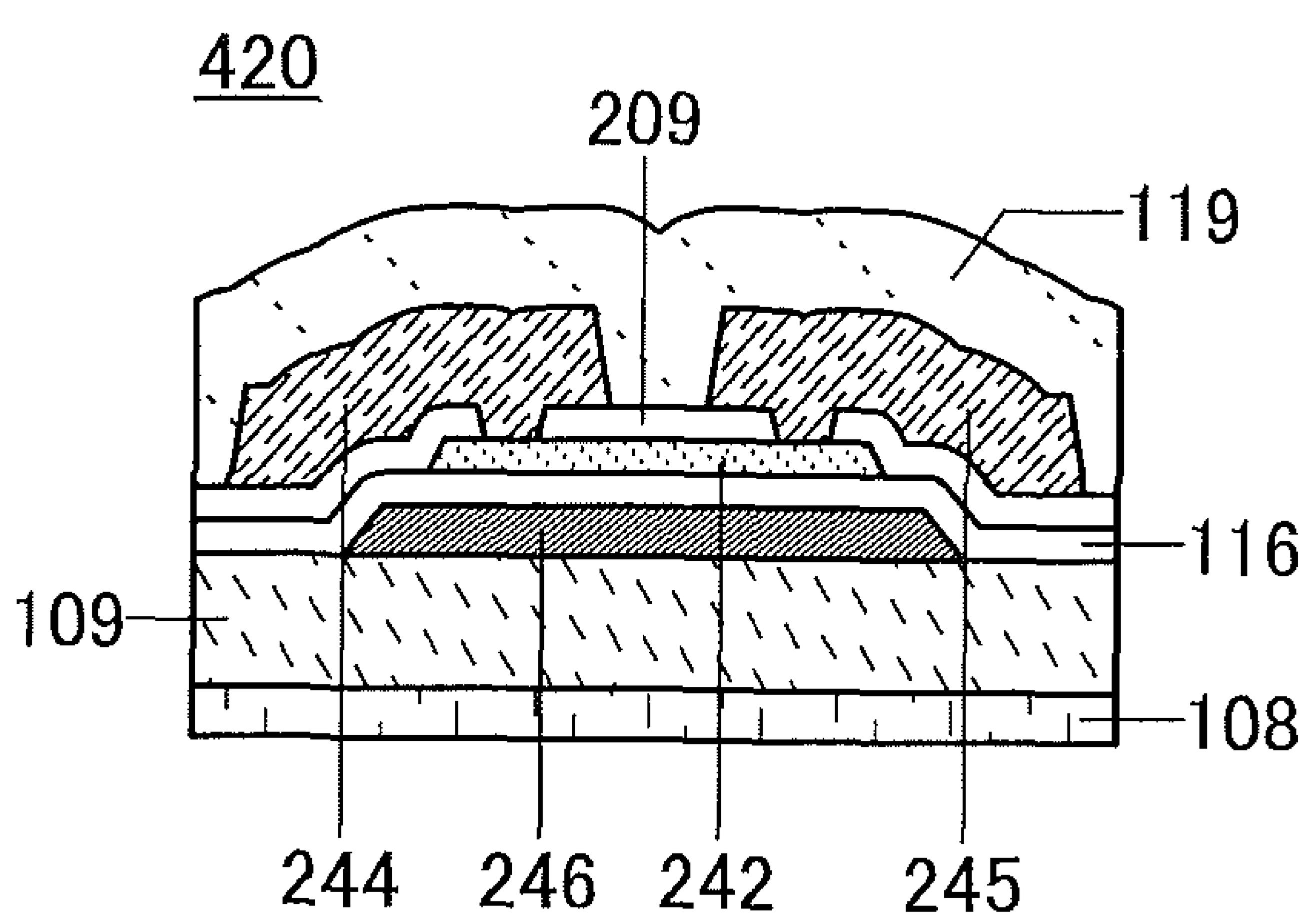


FIG. 45B2

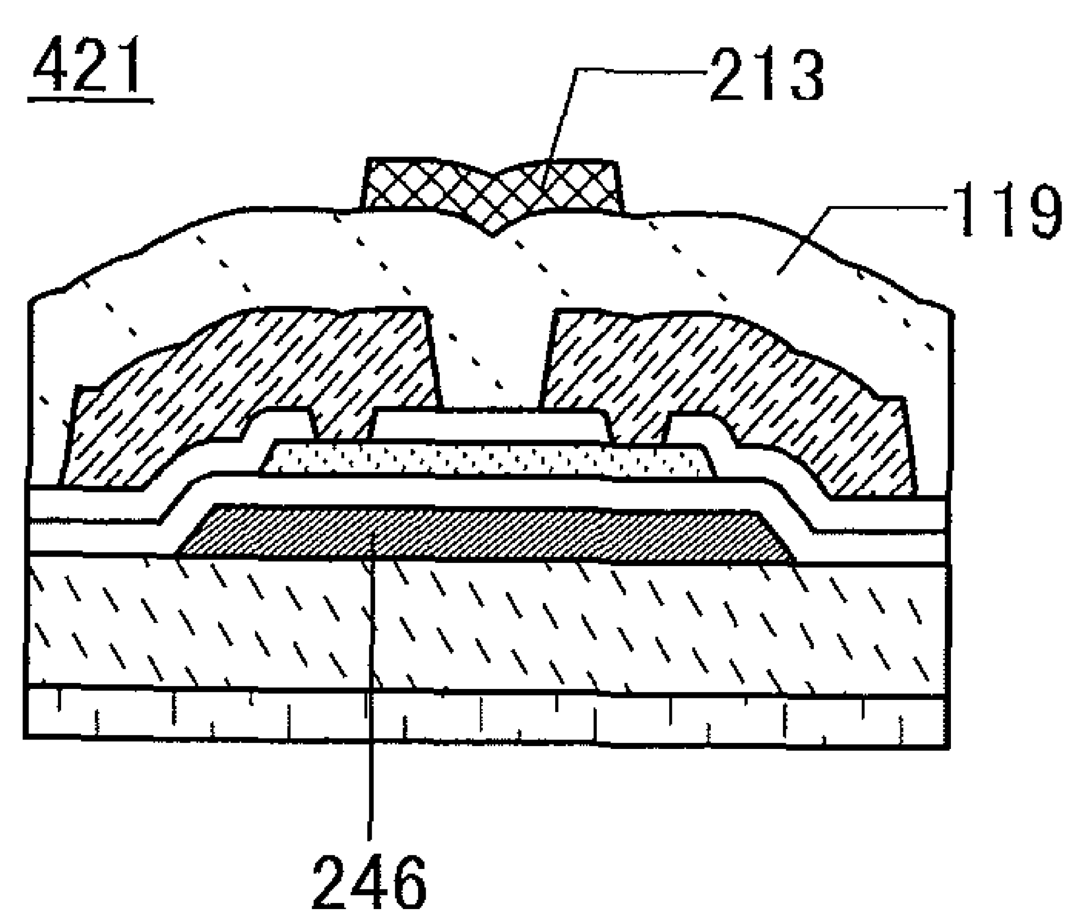


FIG. 46A1

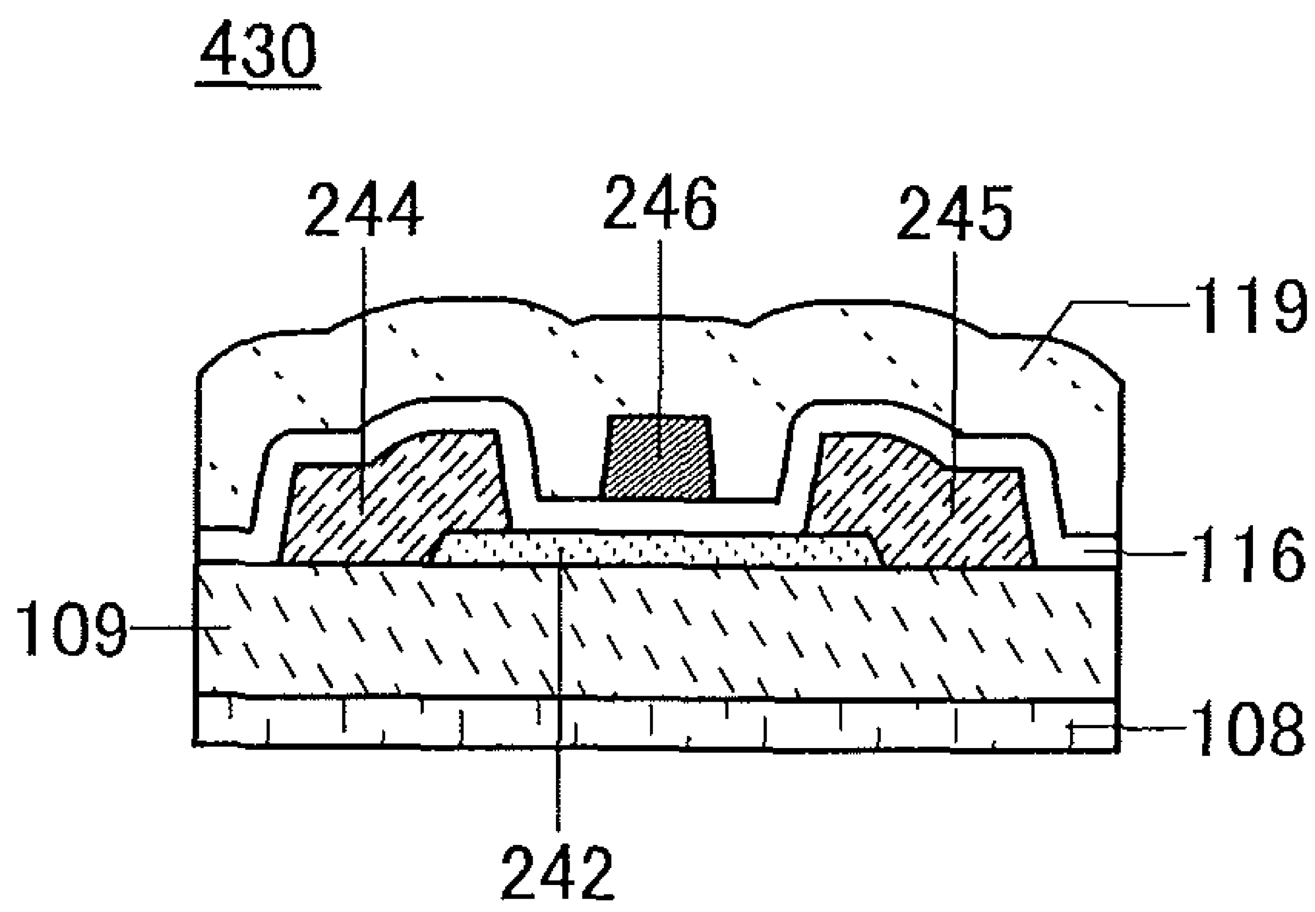


FIG. 46A2

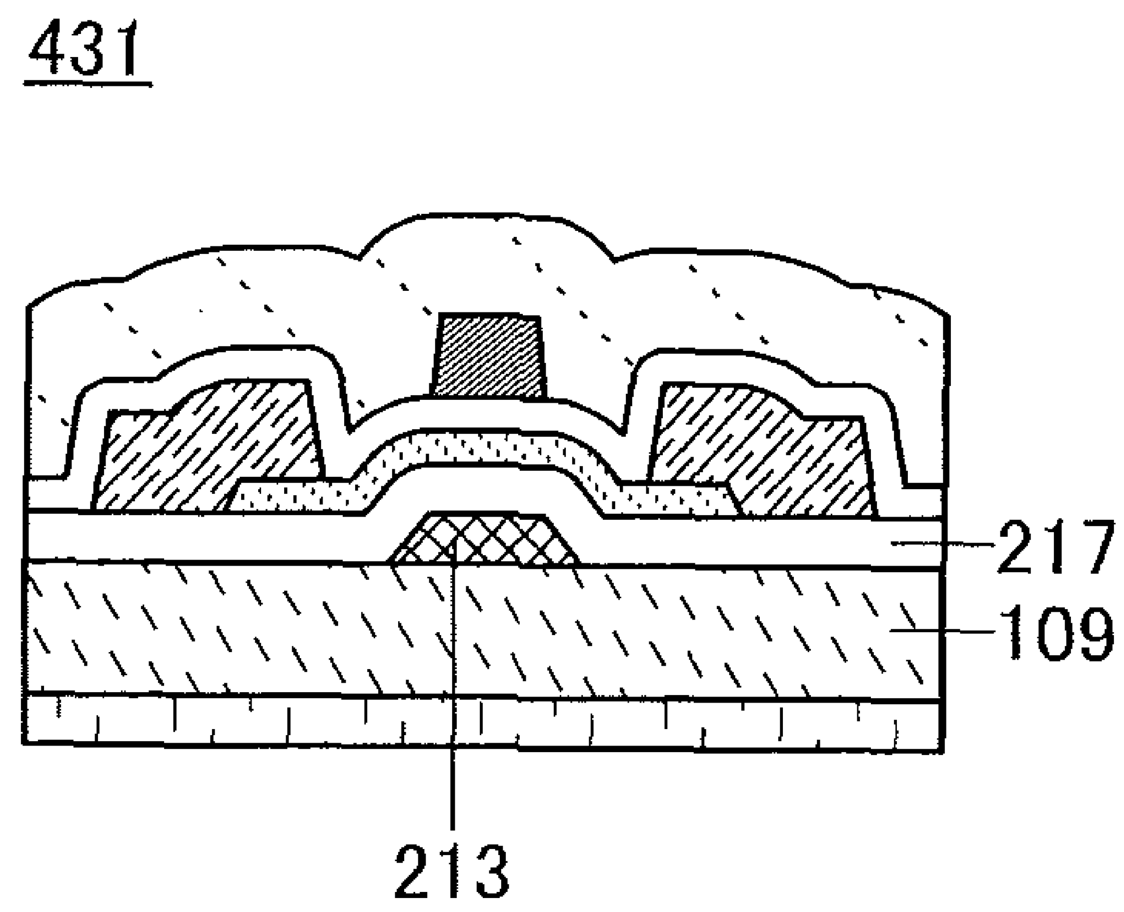


FIG. 46A3

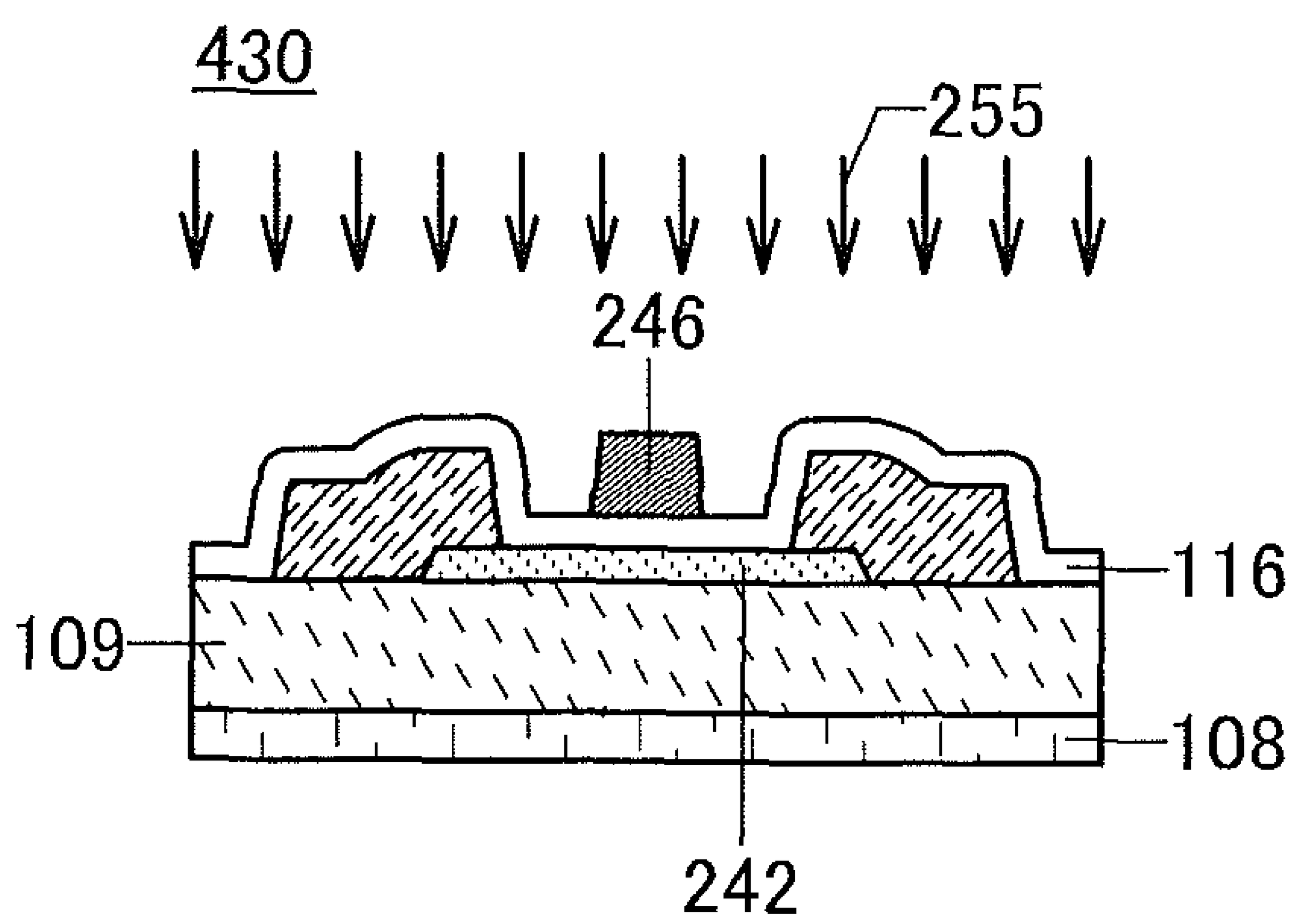


FIG. 46B1

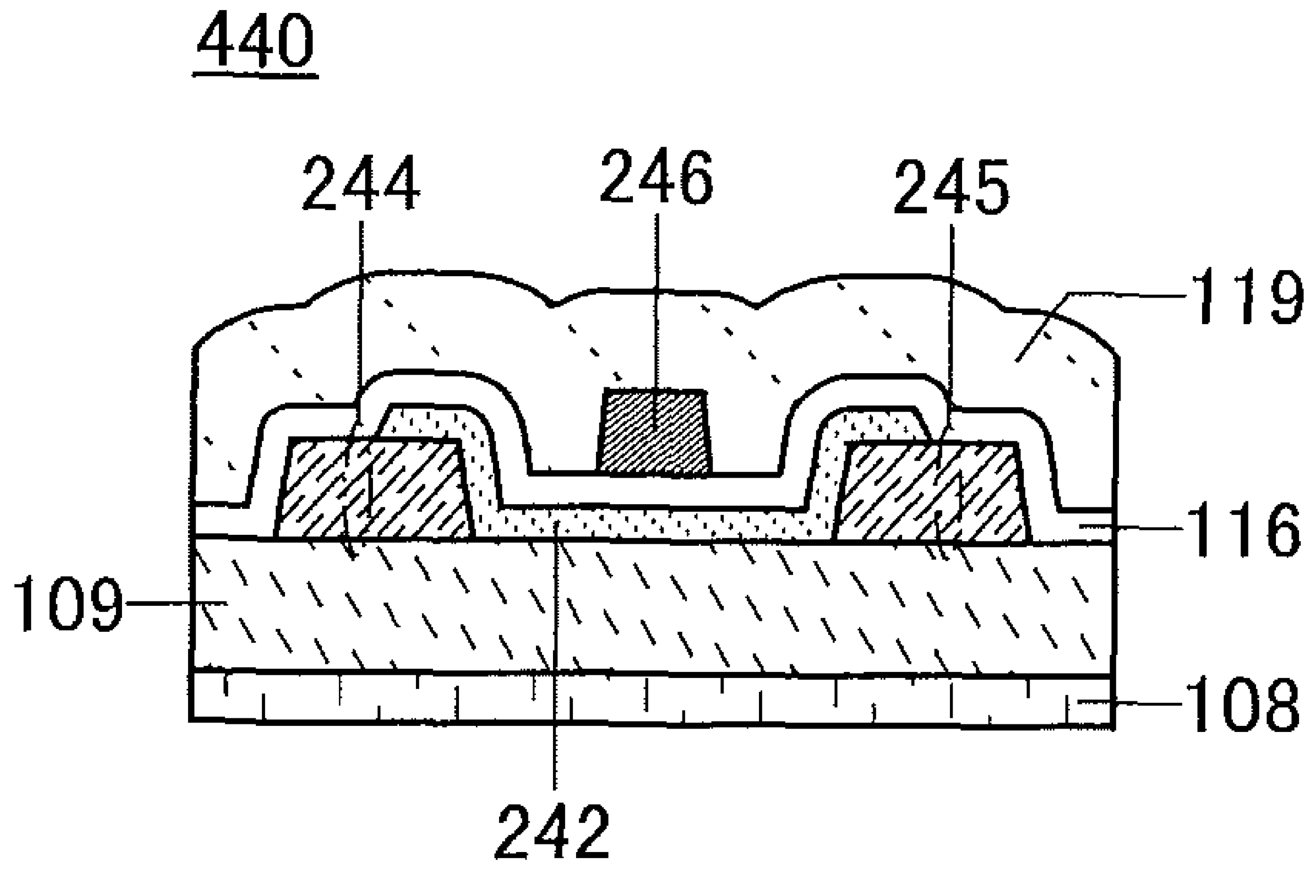


FIG. 46B2

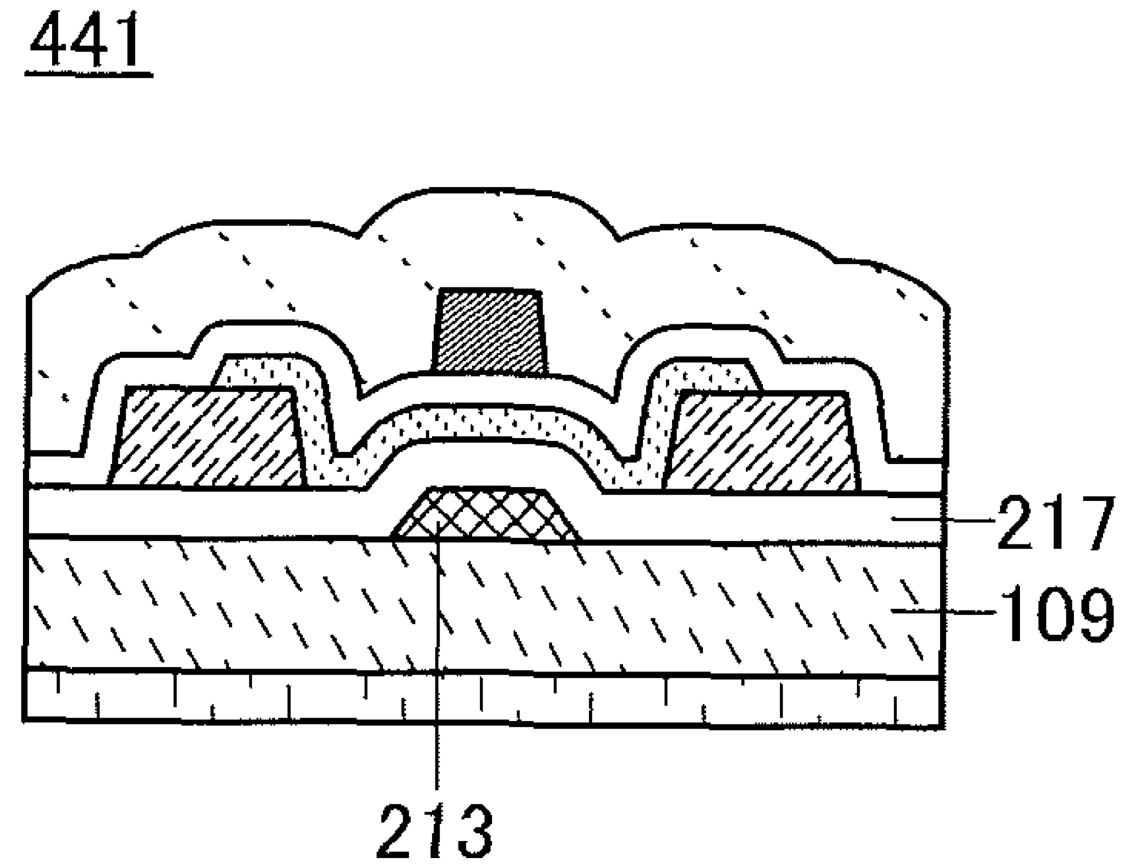


FIG. 47A

450

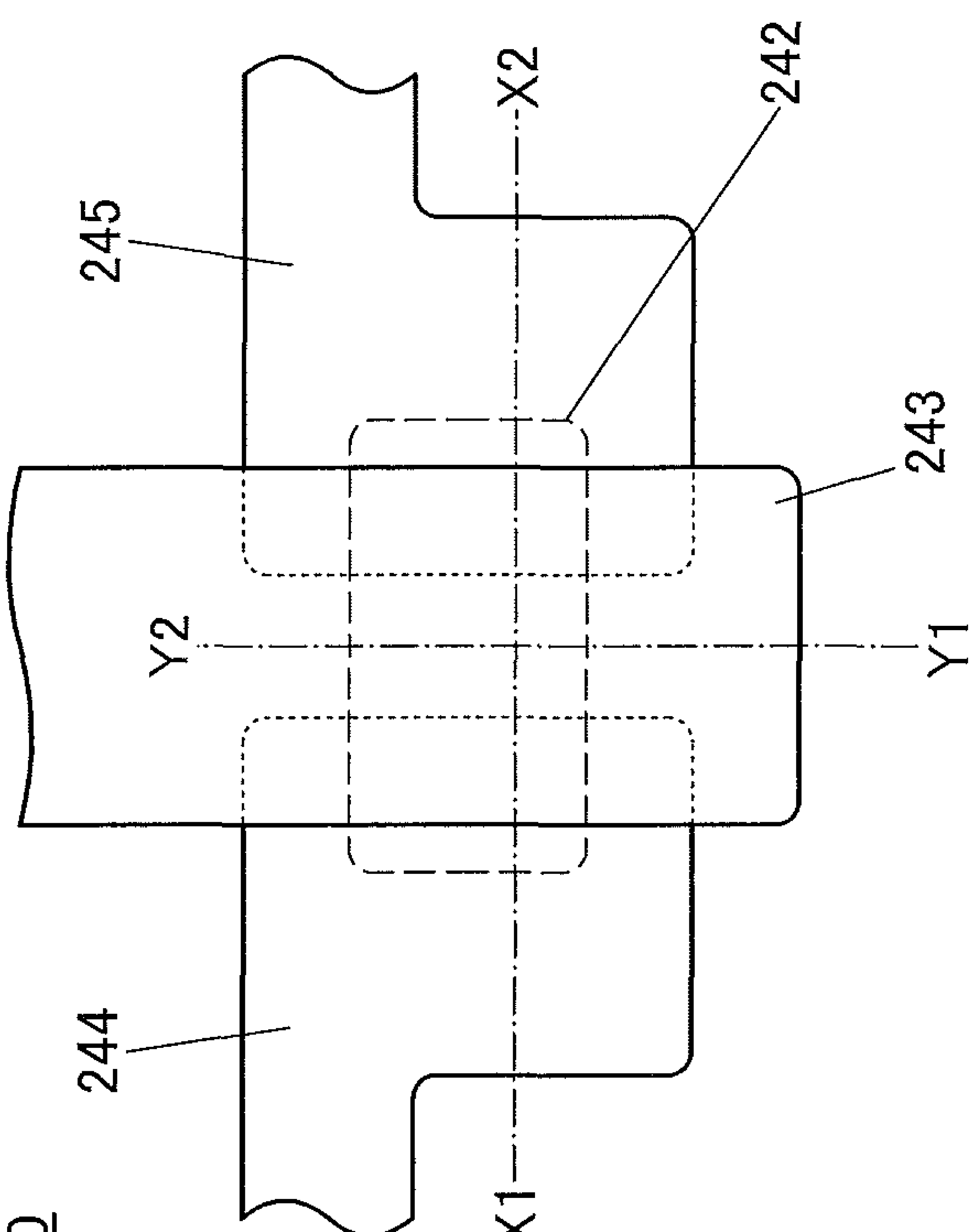


FIG. 47B

450

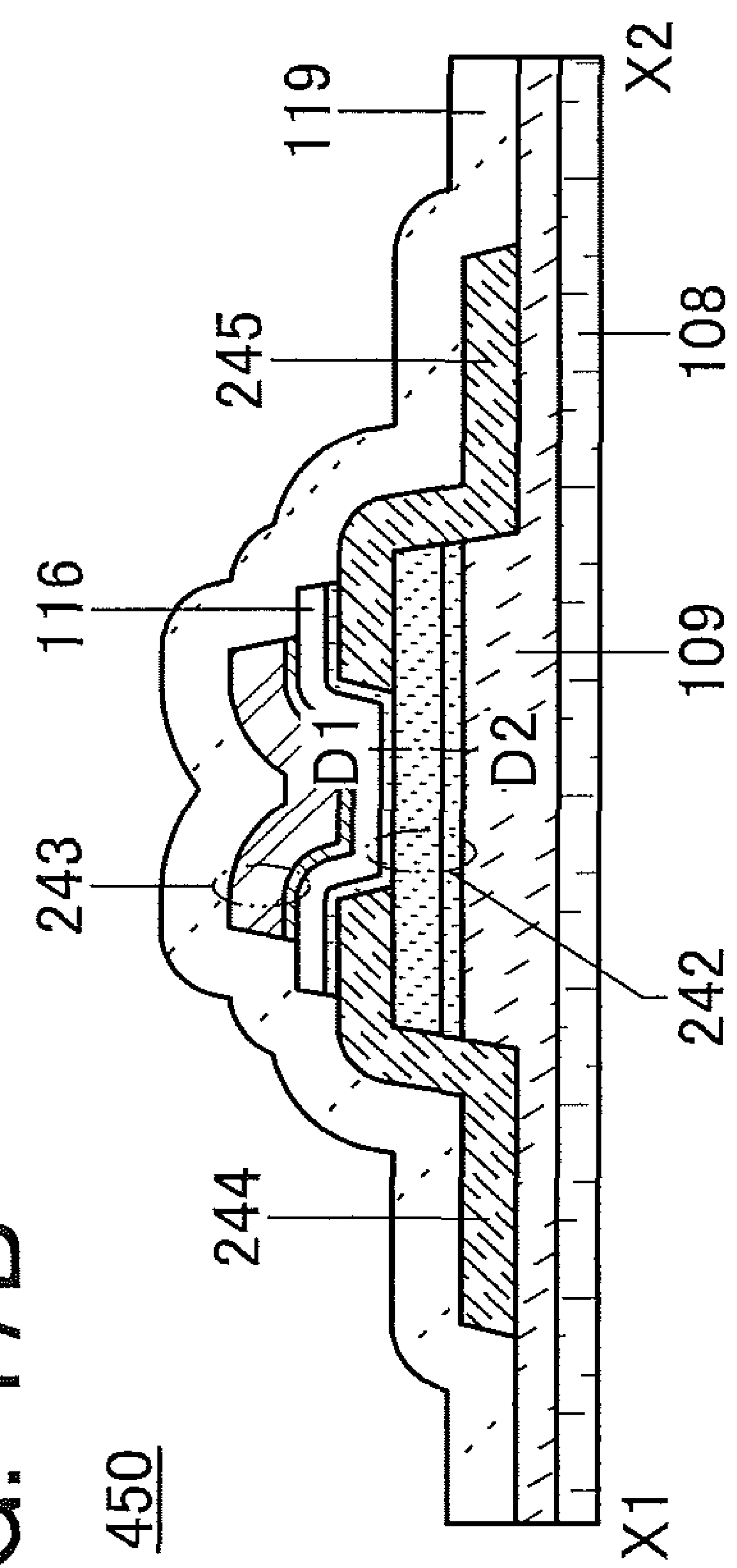


FIG. 47C

450

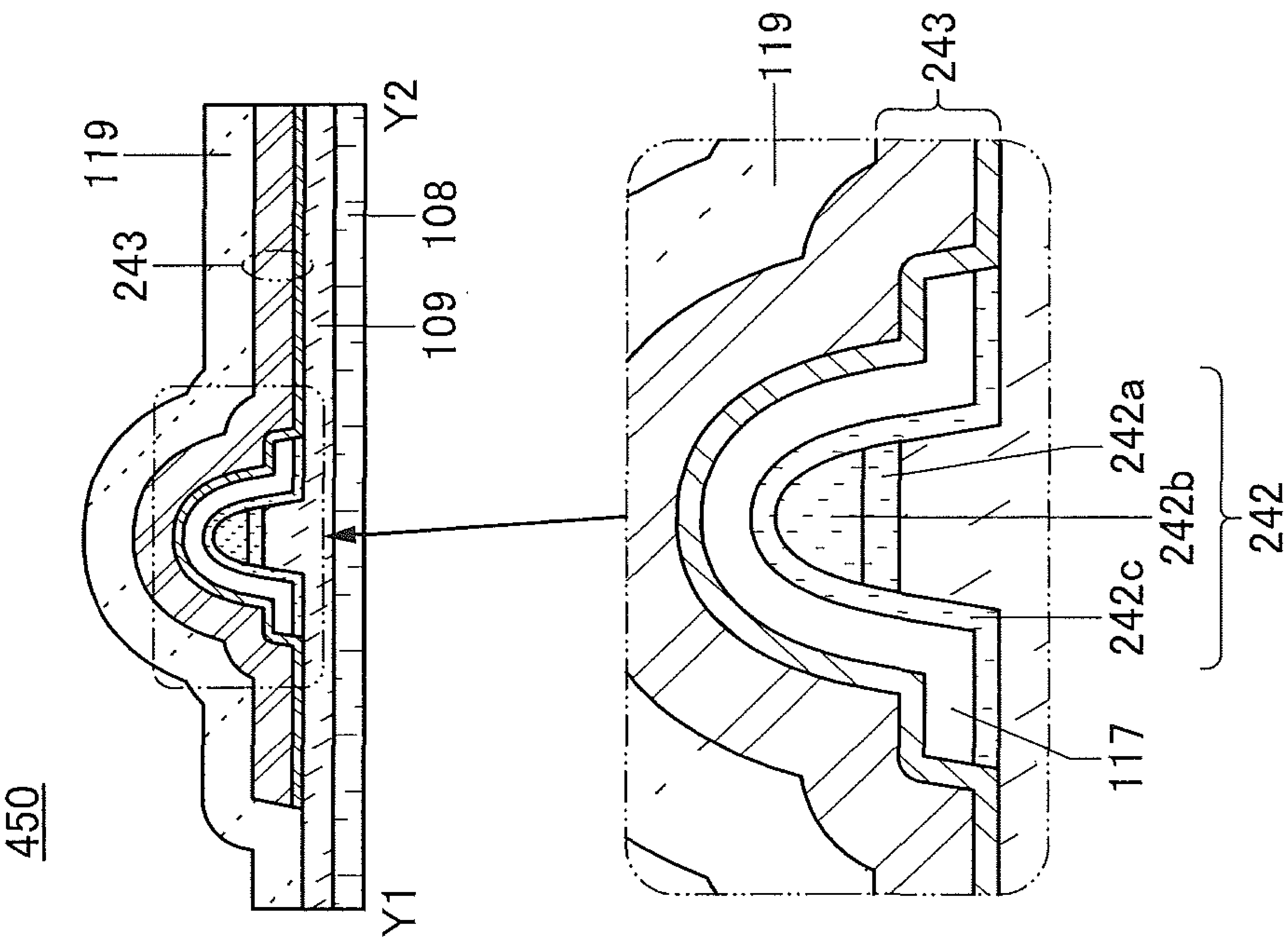


FIG. 48A

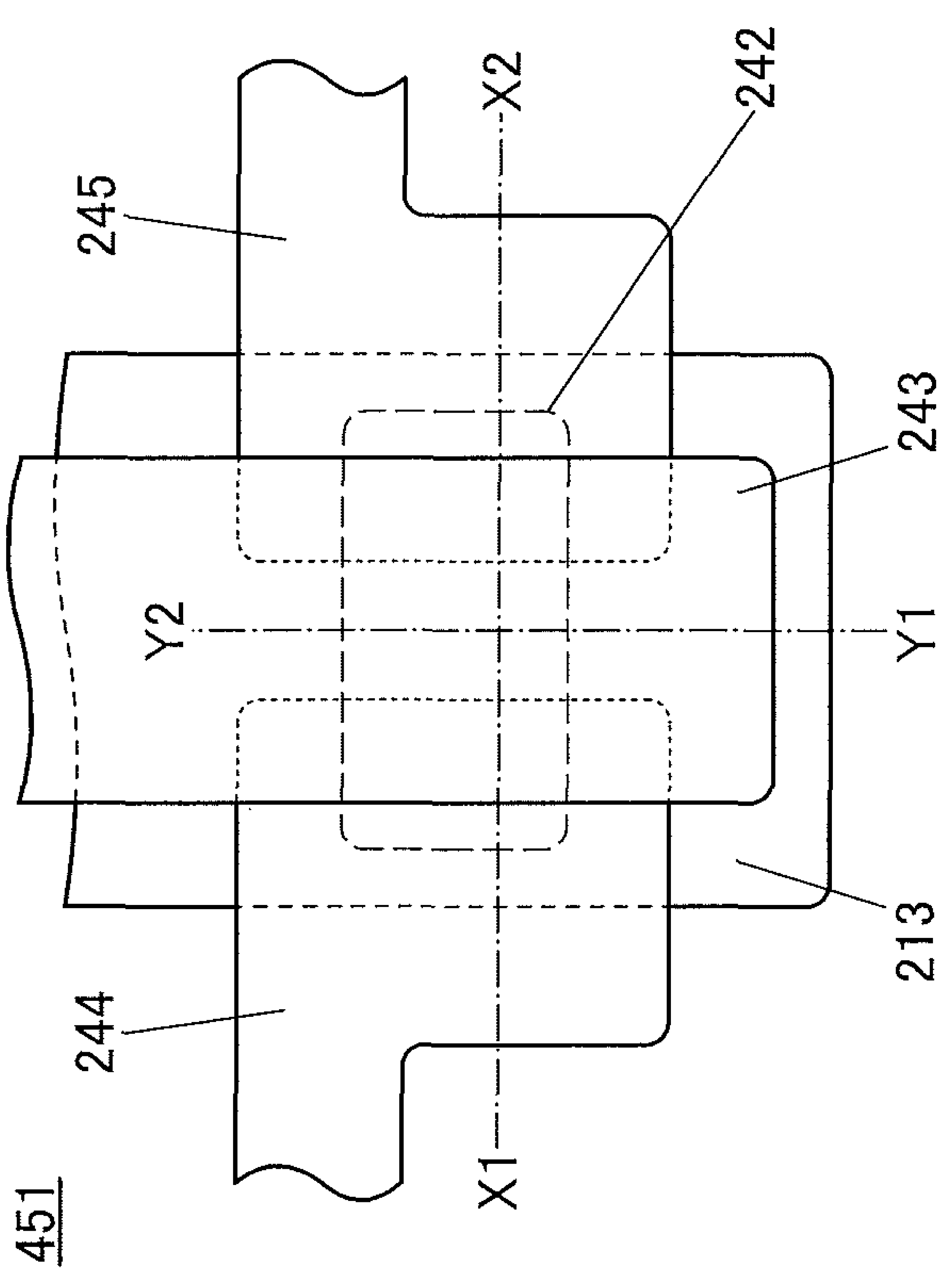


FIG. 48B

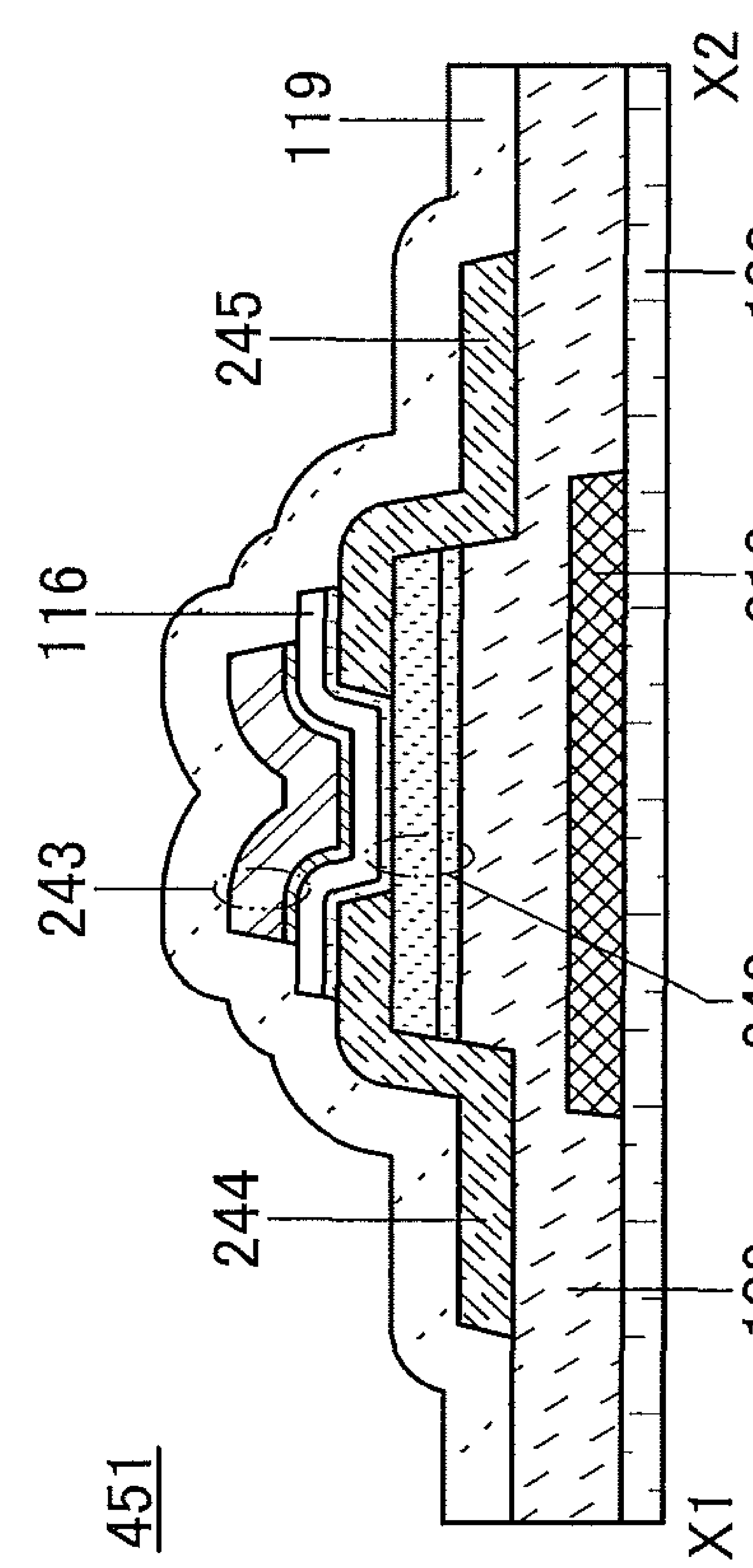


FIG. 48C

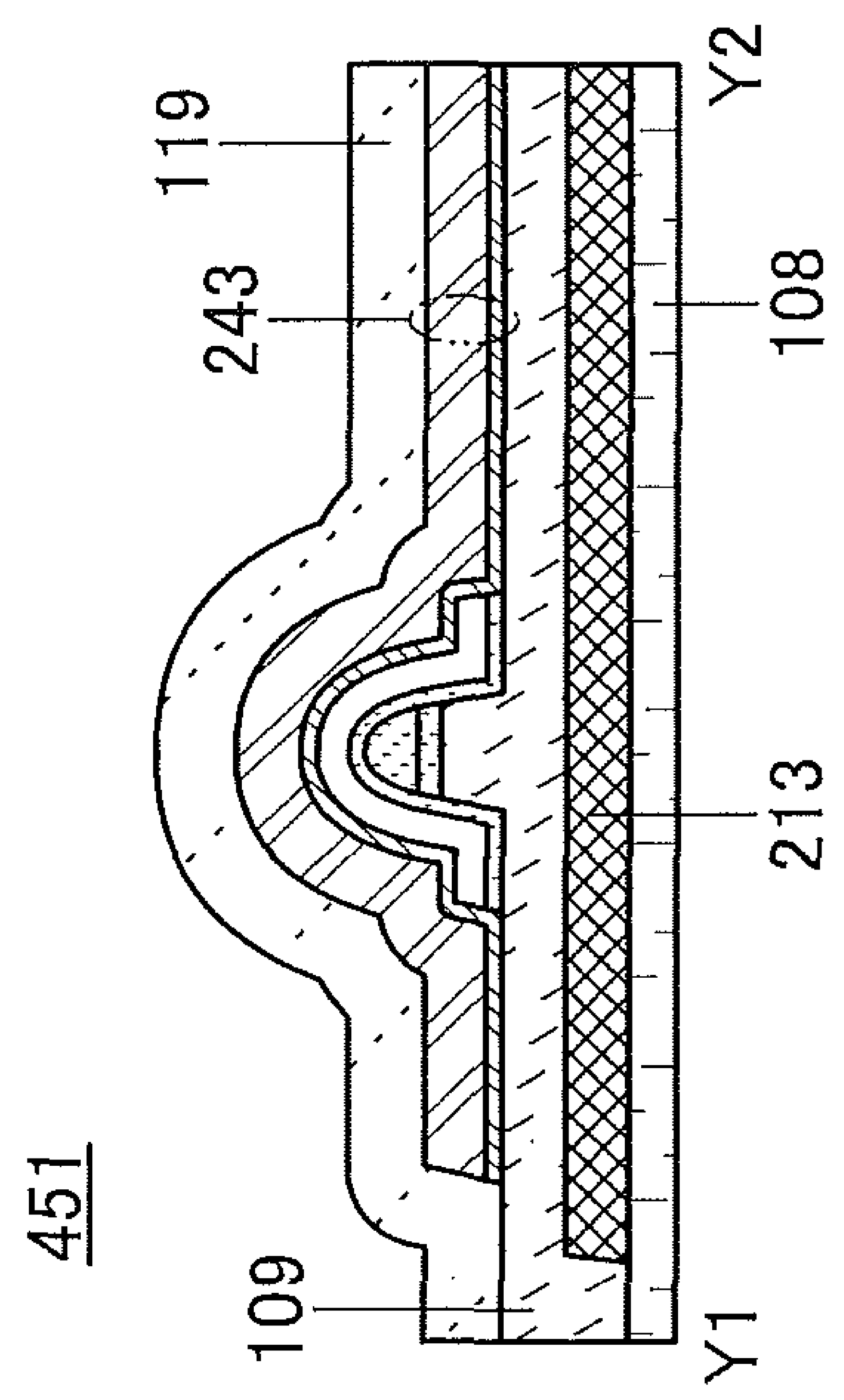


FIG. 49C
452

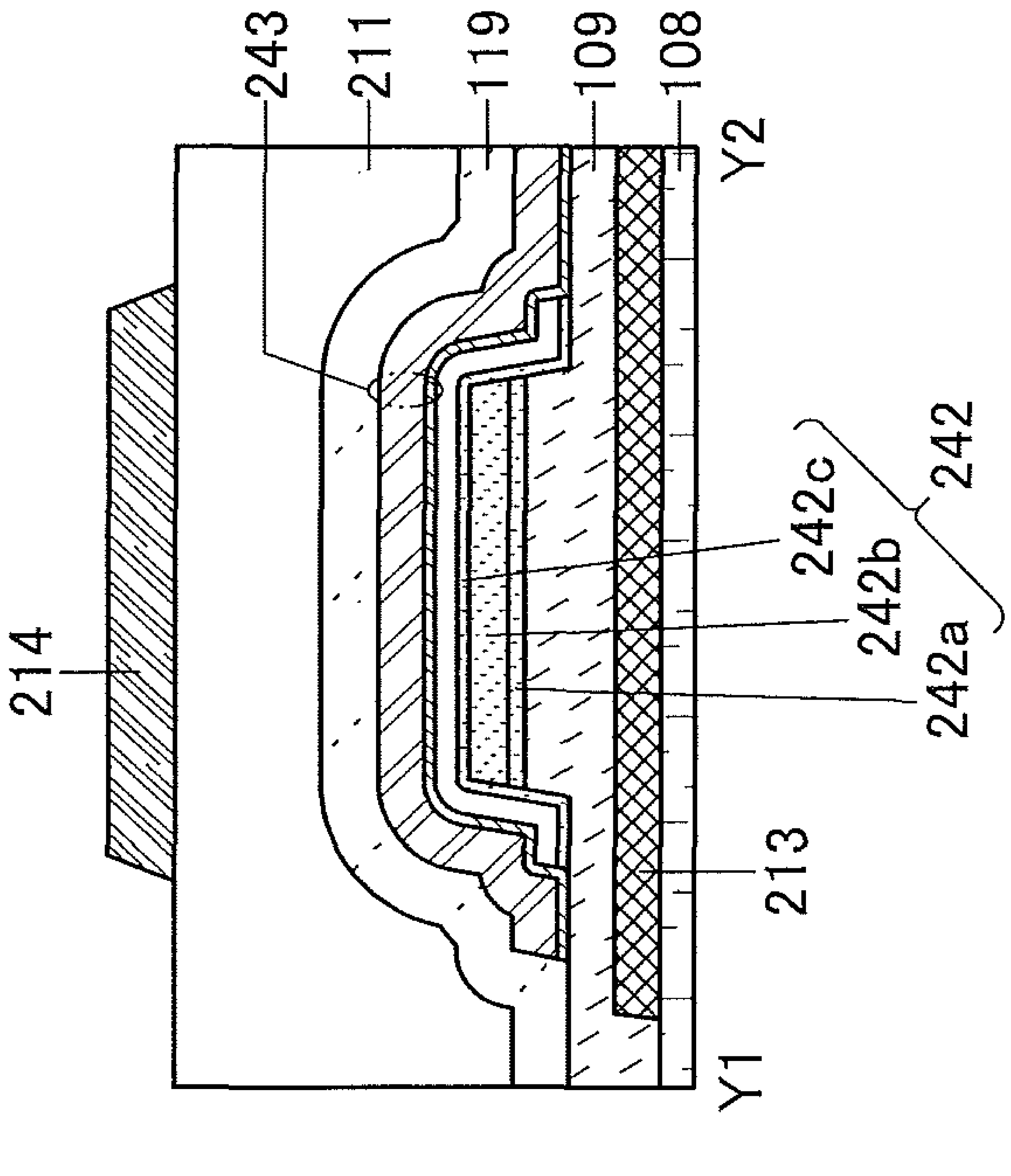


FIG. 49A
452

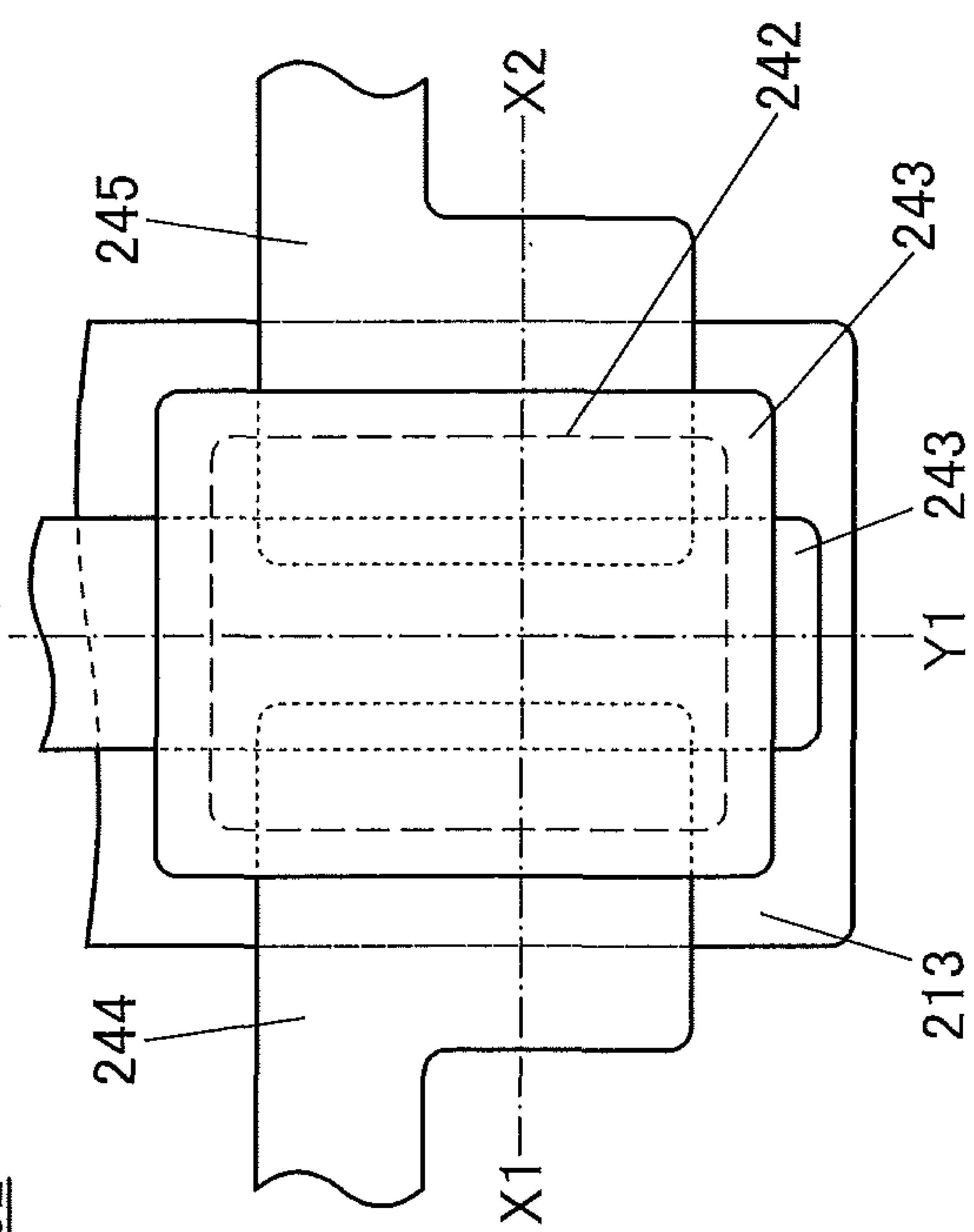


FIG. 49B
452

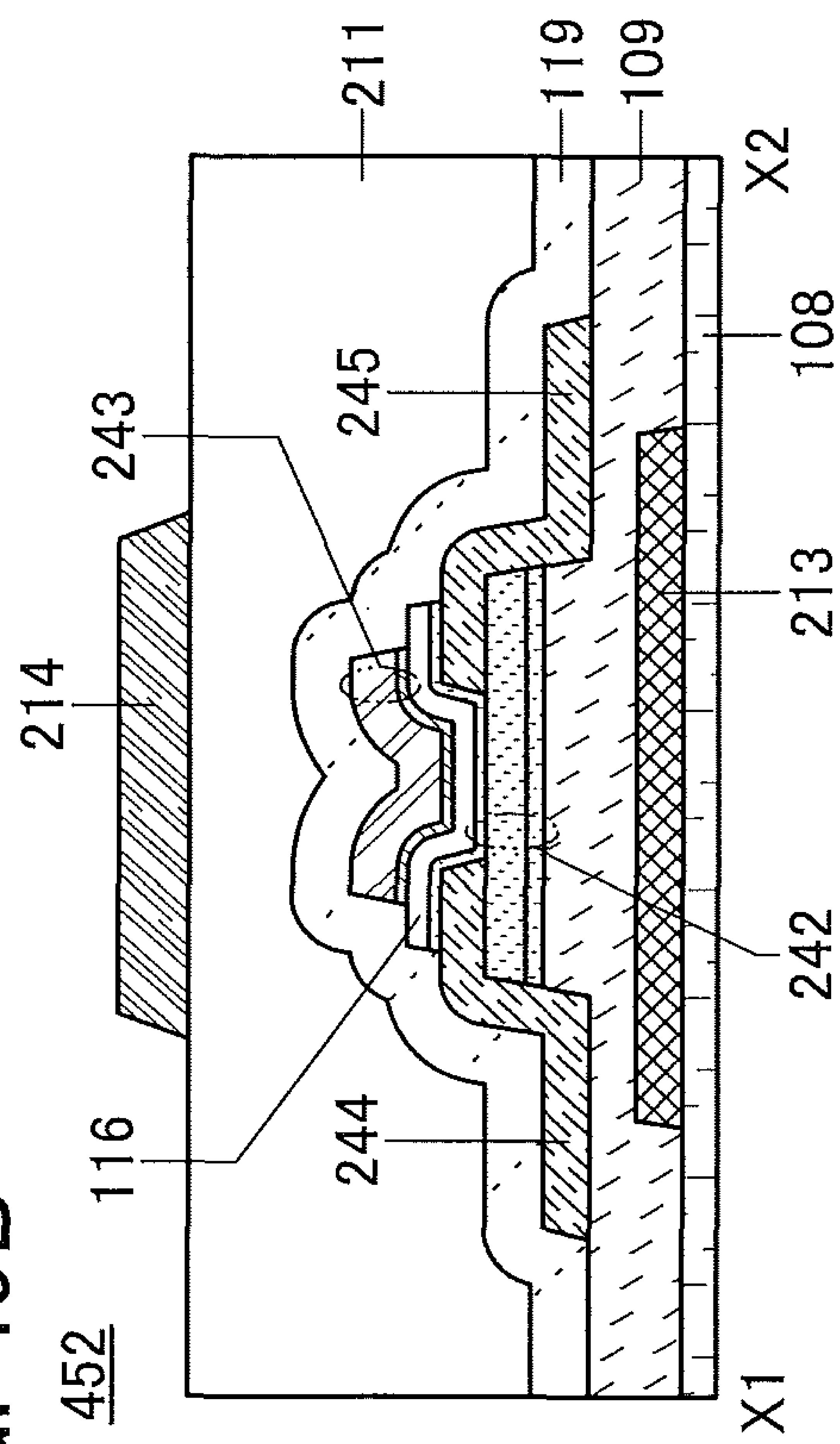


FIG. 50

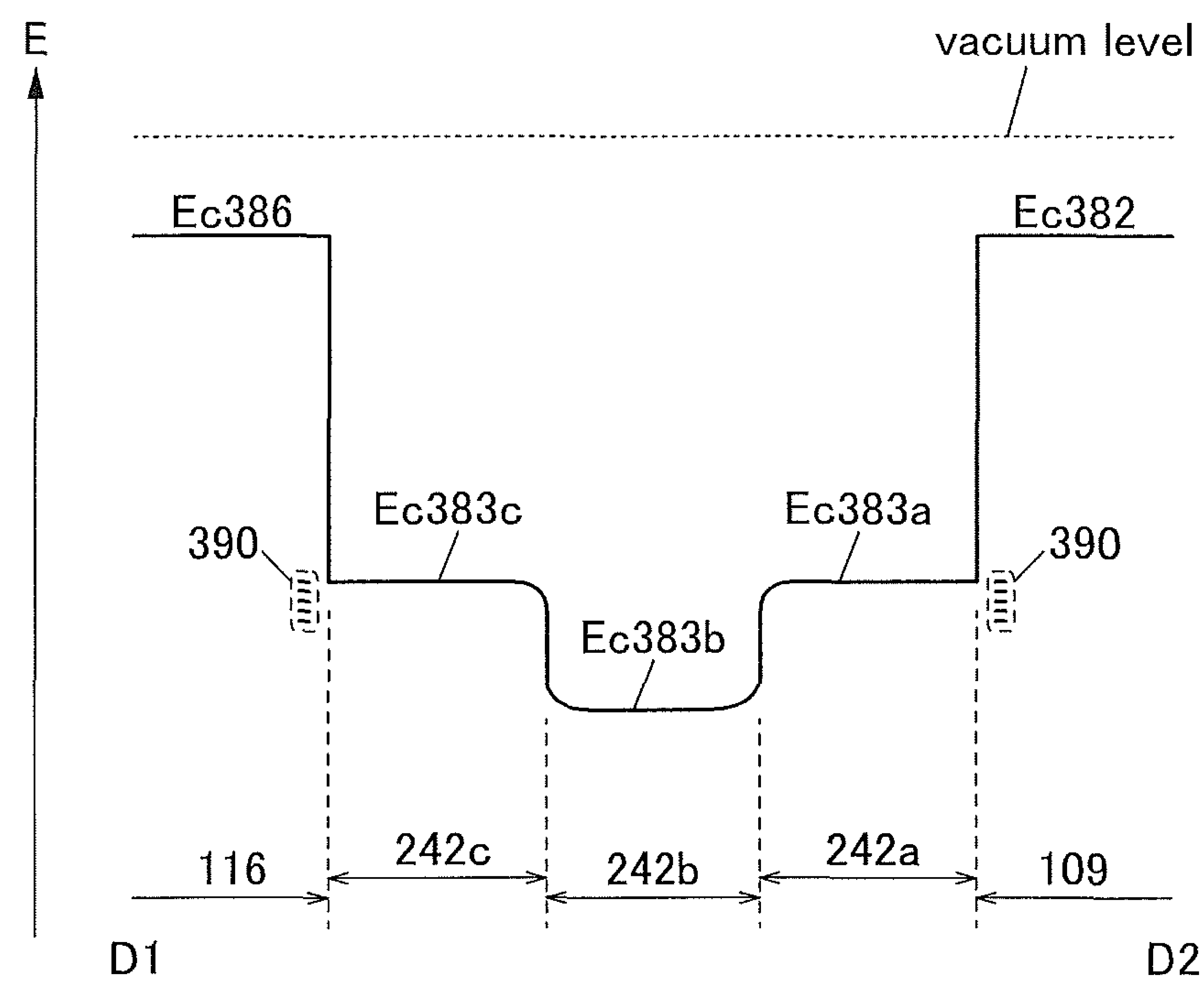

E
vacuum level
Ec386
Ec382
Ec383c
Ec383a
390
390
Ec383b
116
242c
242b
242a
109
D1
D2

FIG. 51A

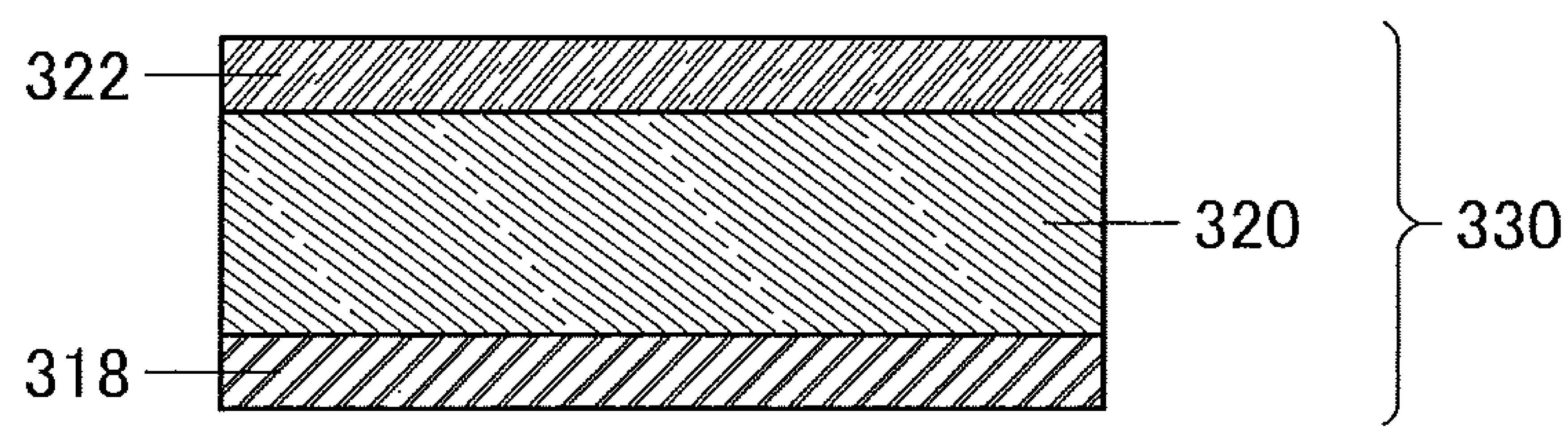


FIG. 51B

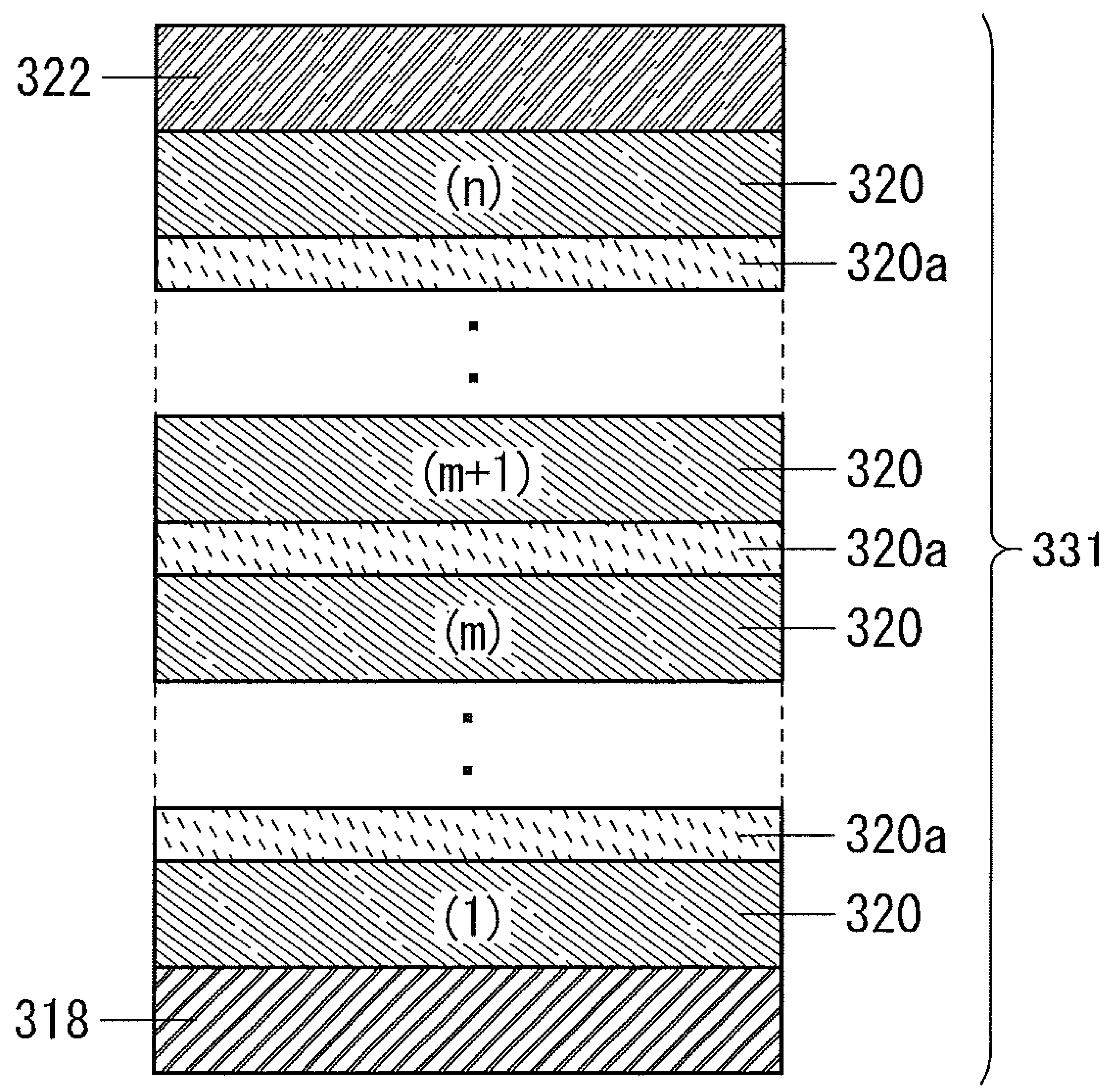


FIG. 52A

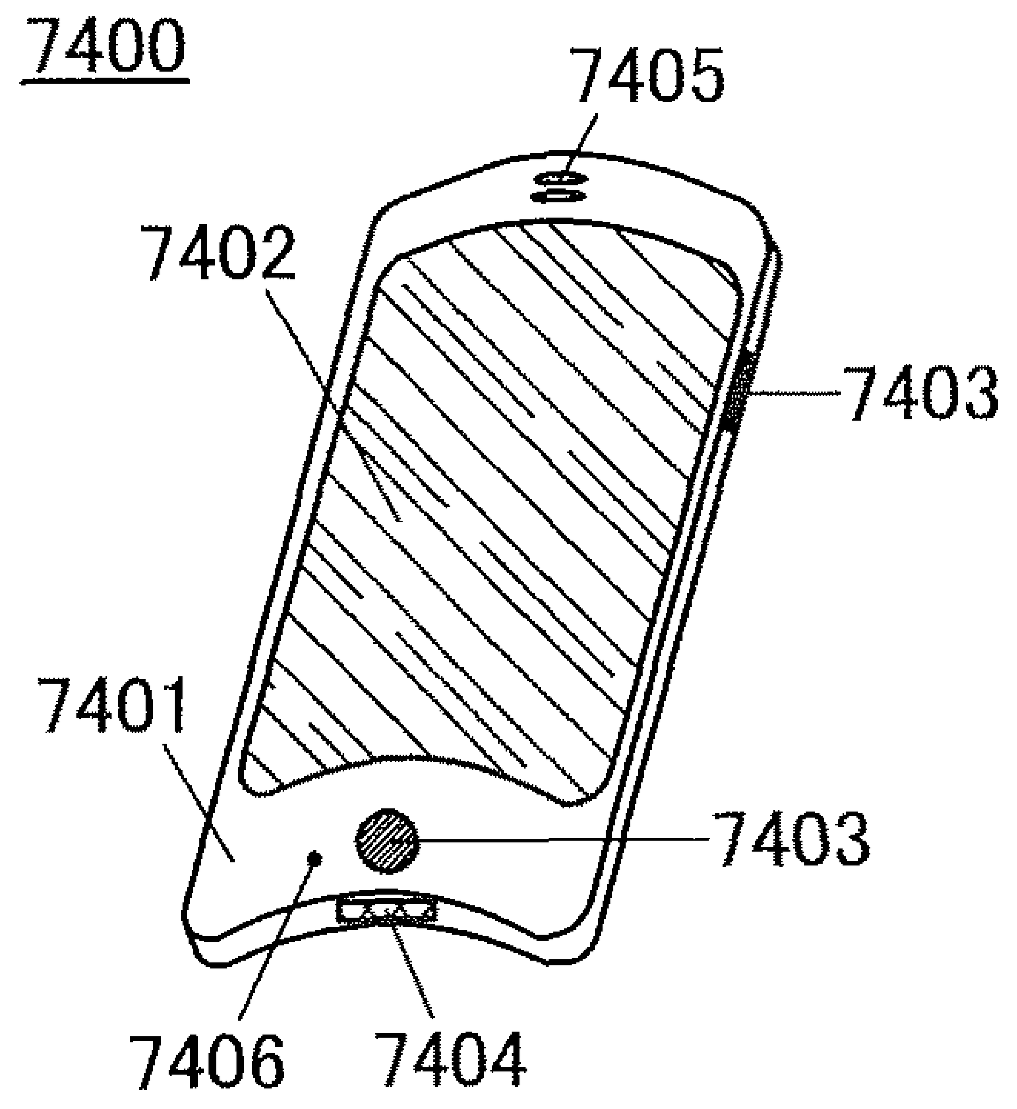


FIG. 52B

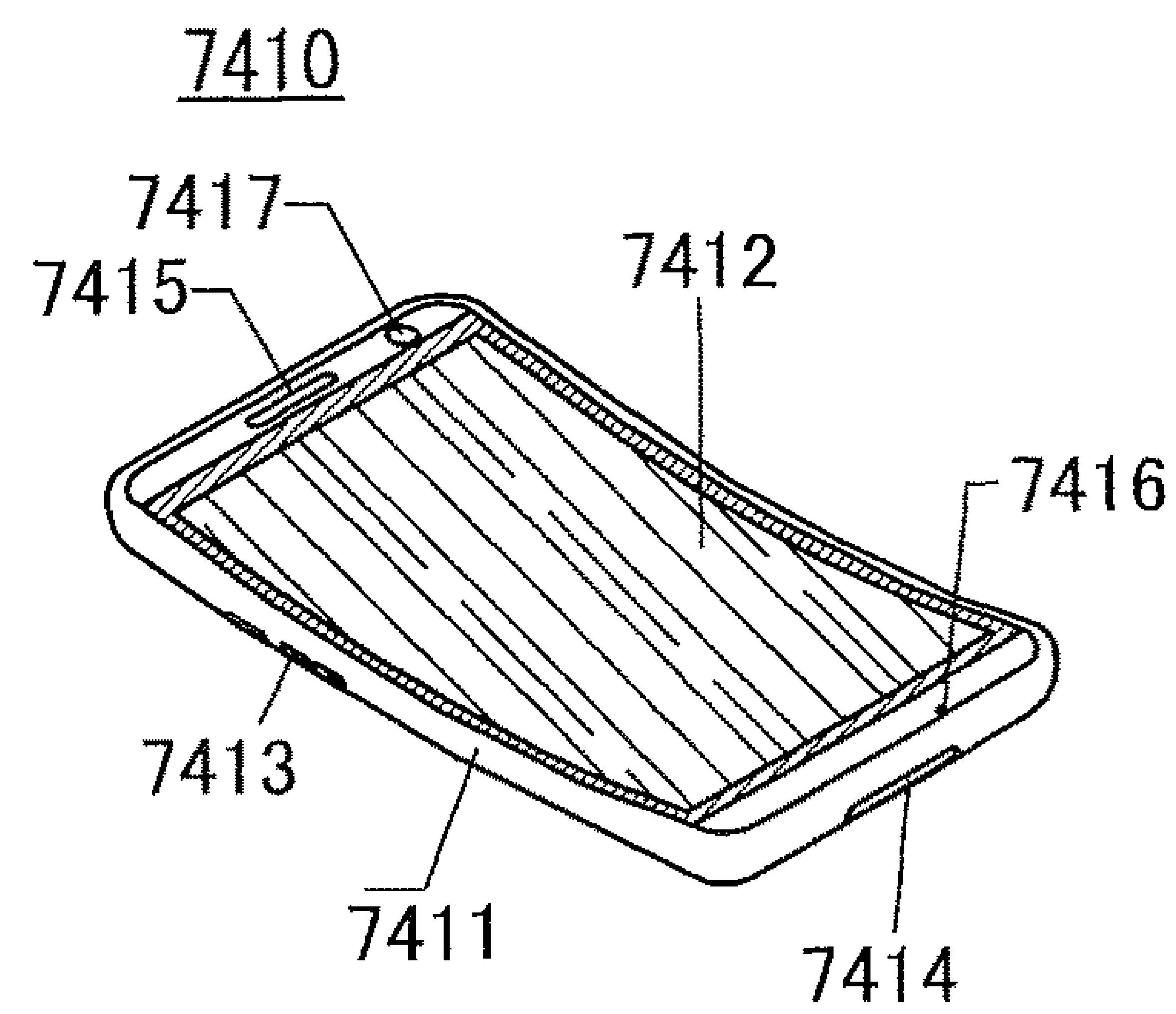


FIG. 52C

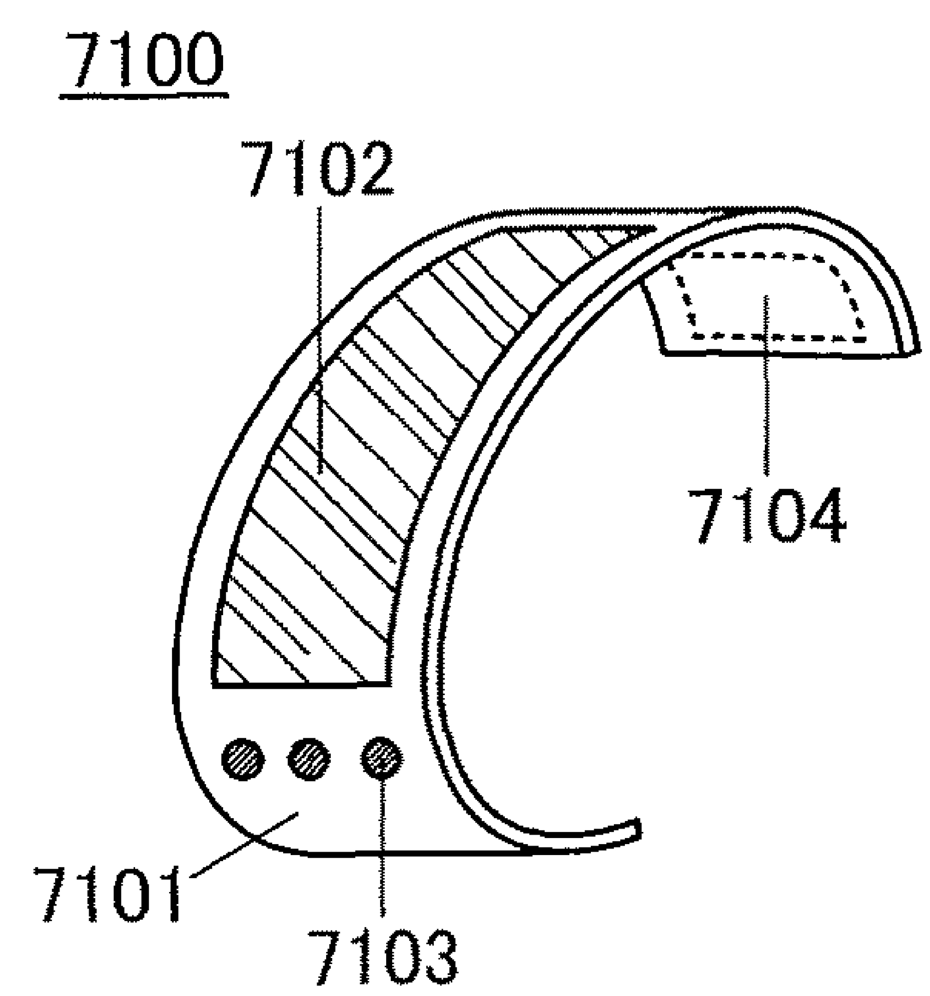


FIG. 52D

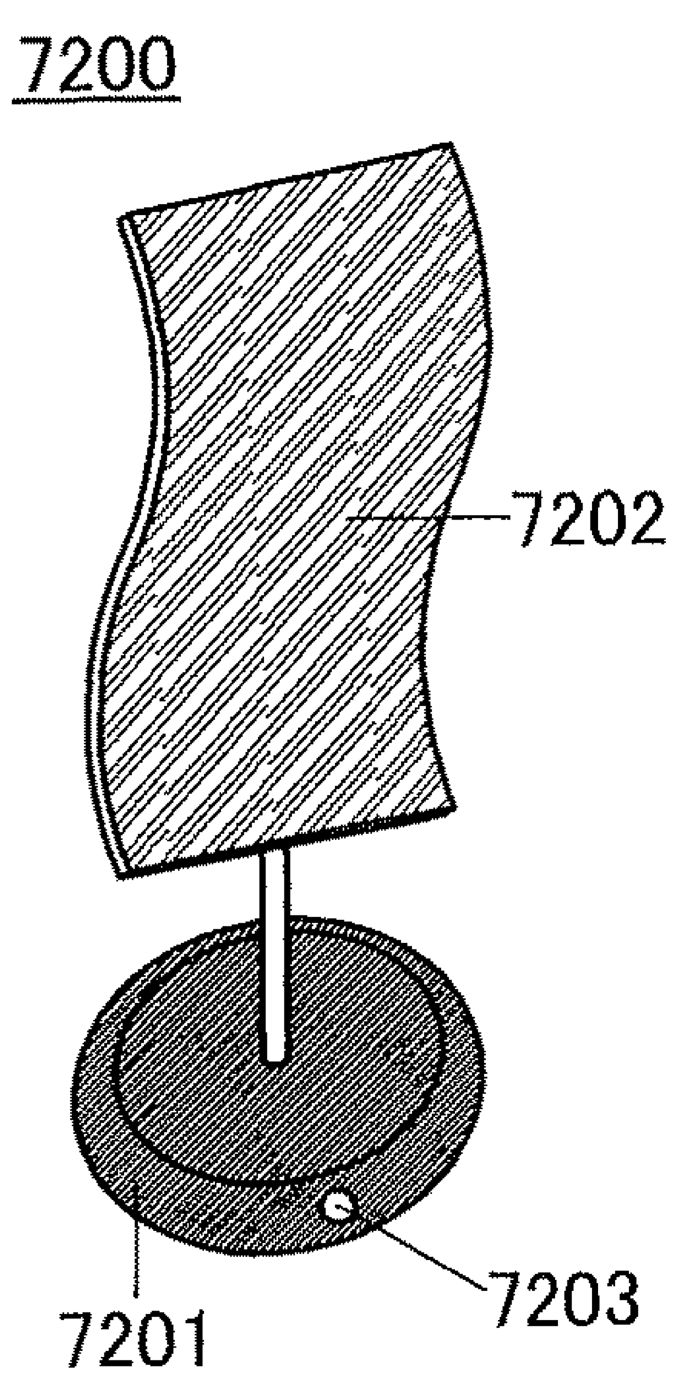


FIG. 52E

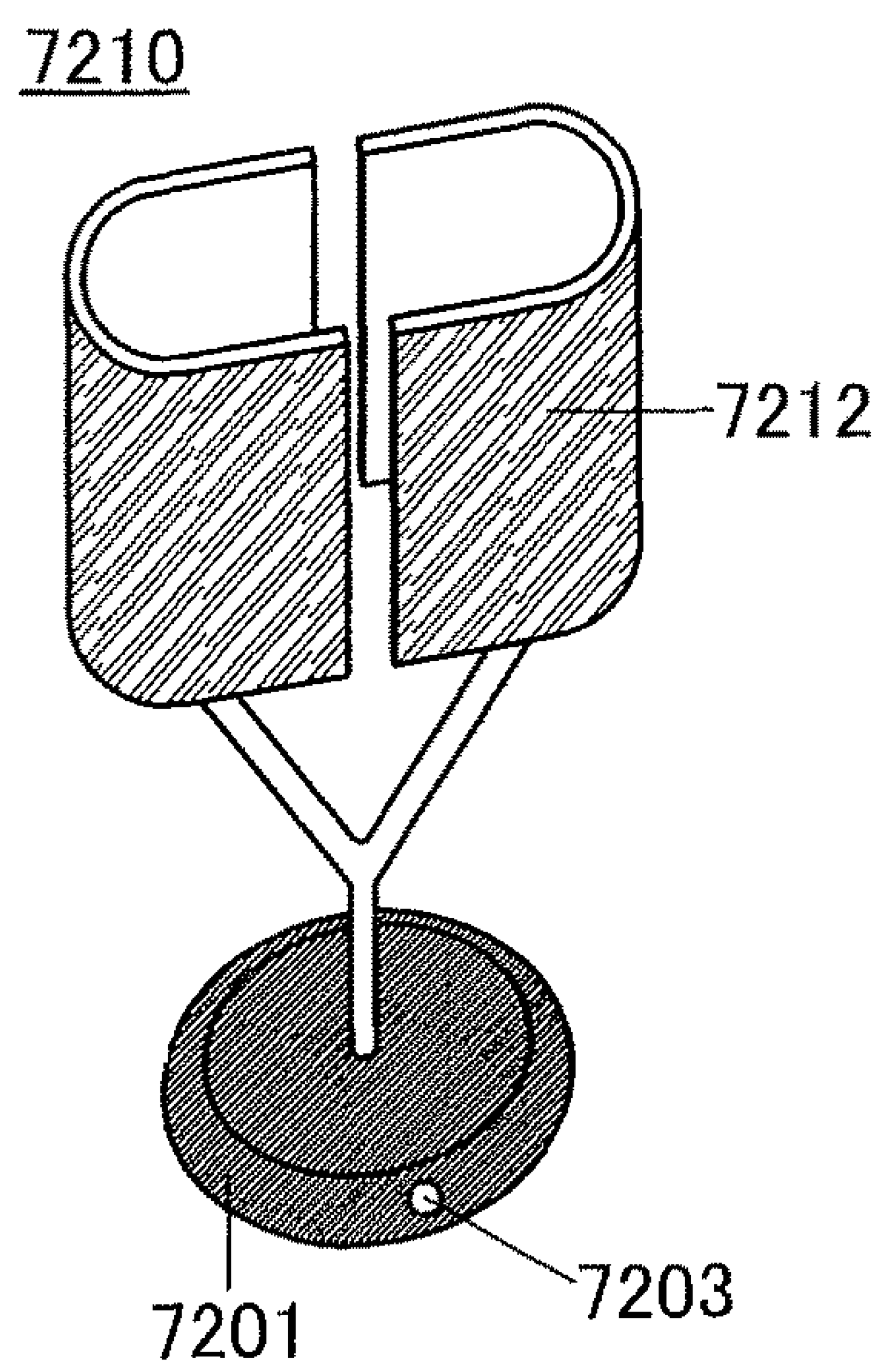


FIG. 52F

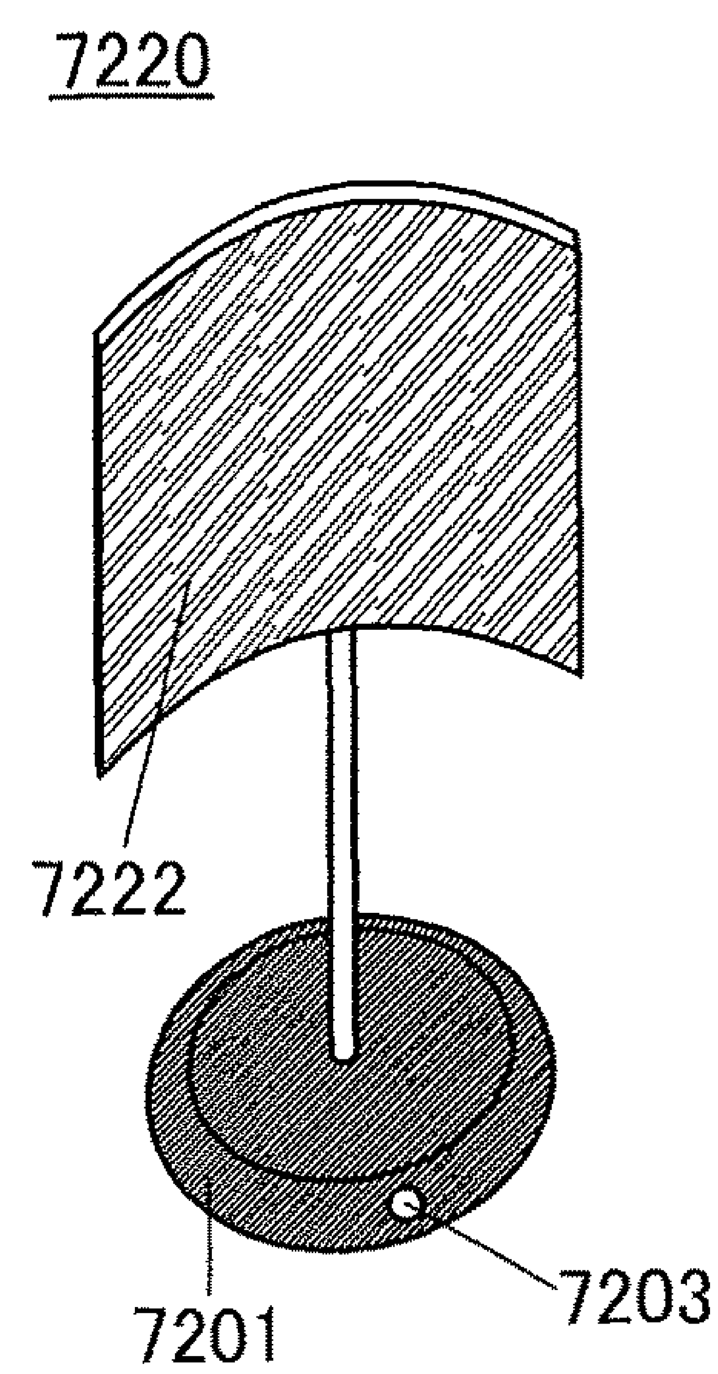


FIG. 53A

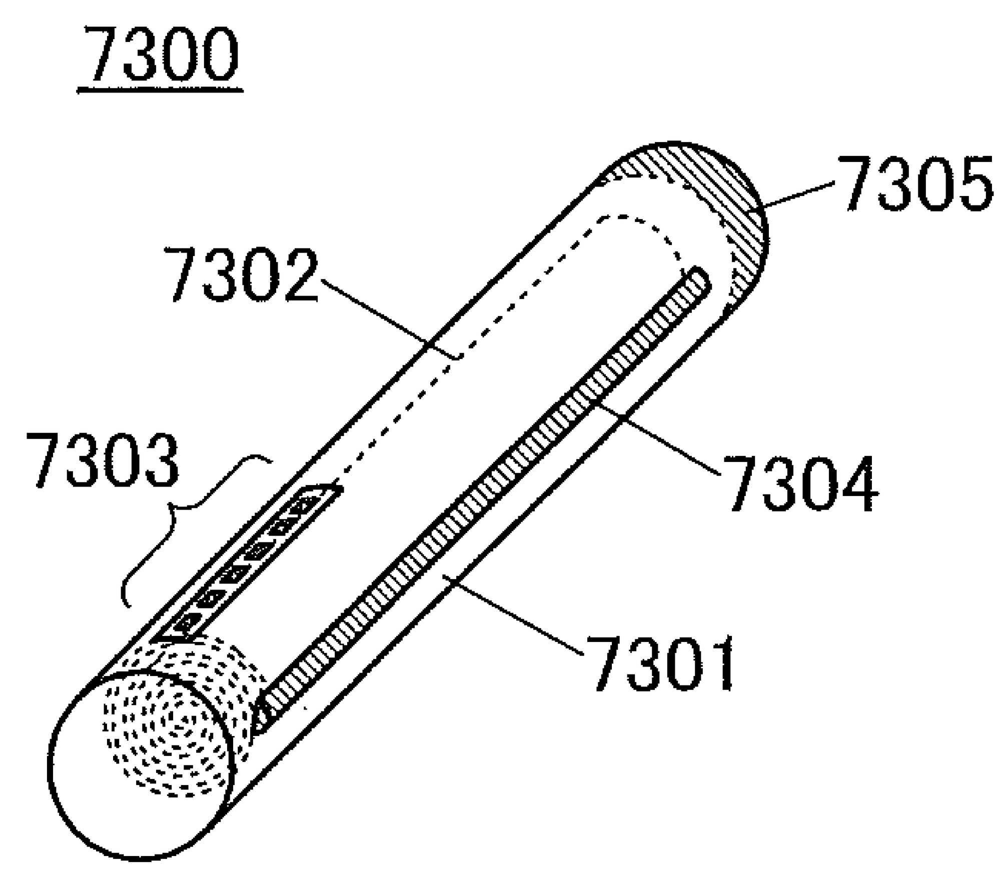


FIG. 53B

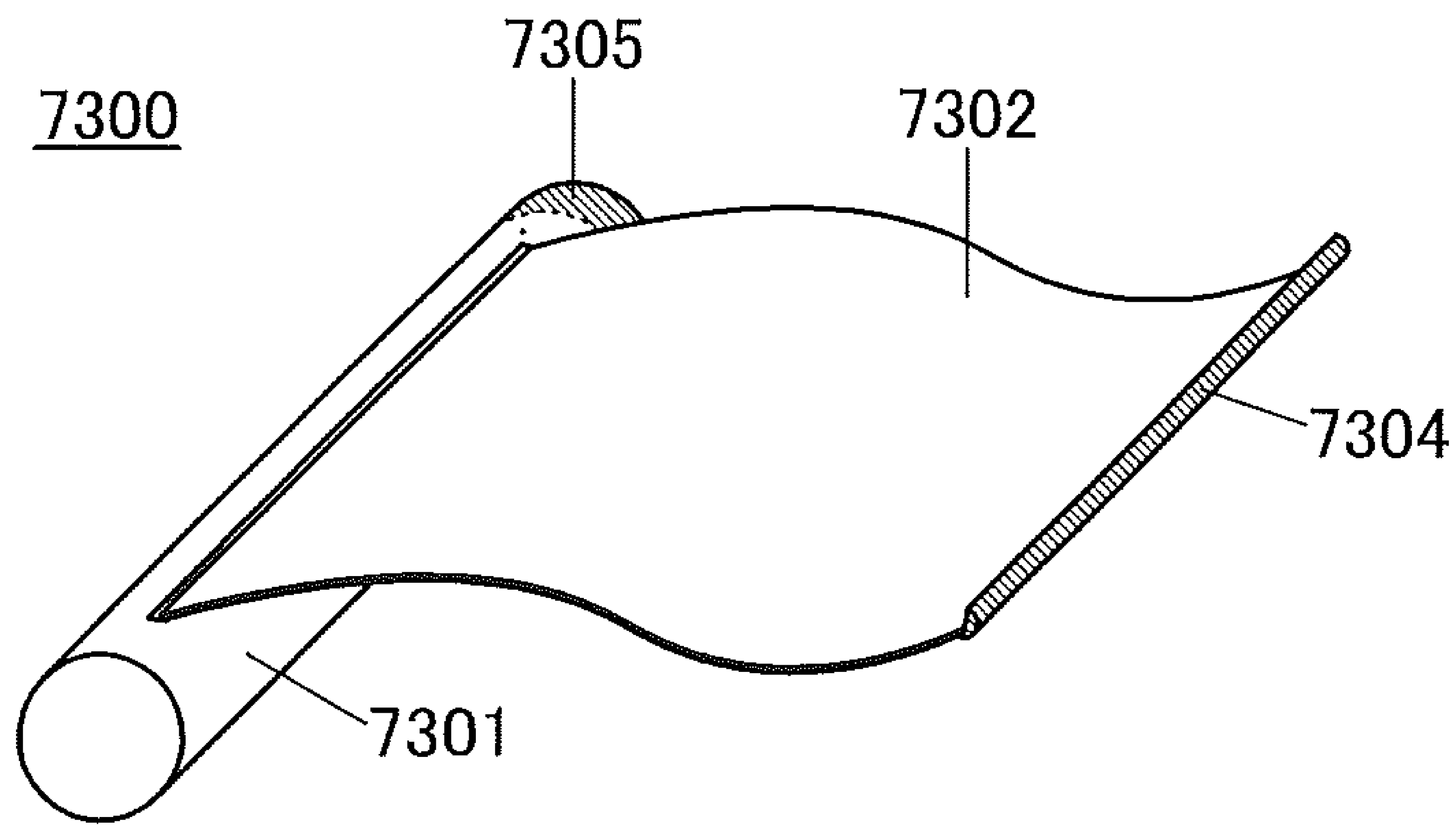


FIG. 54A

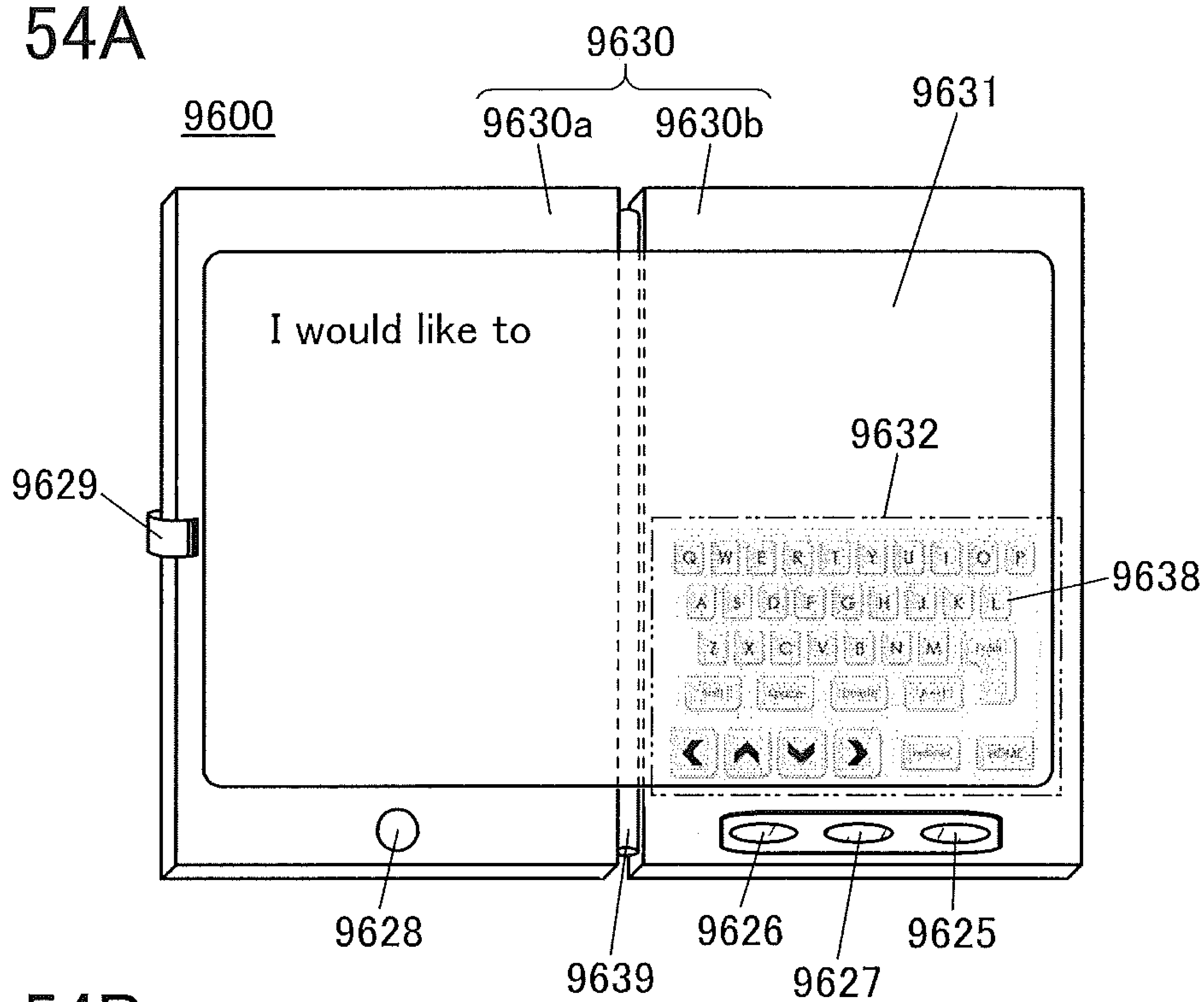


FIG. 54B

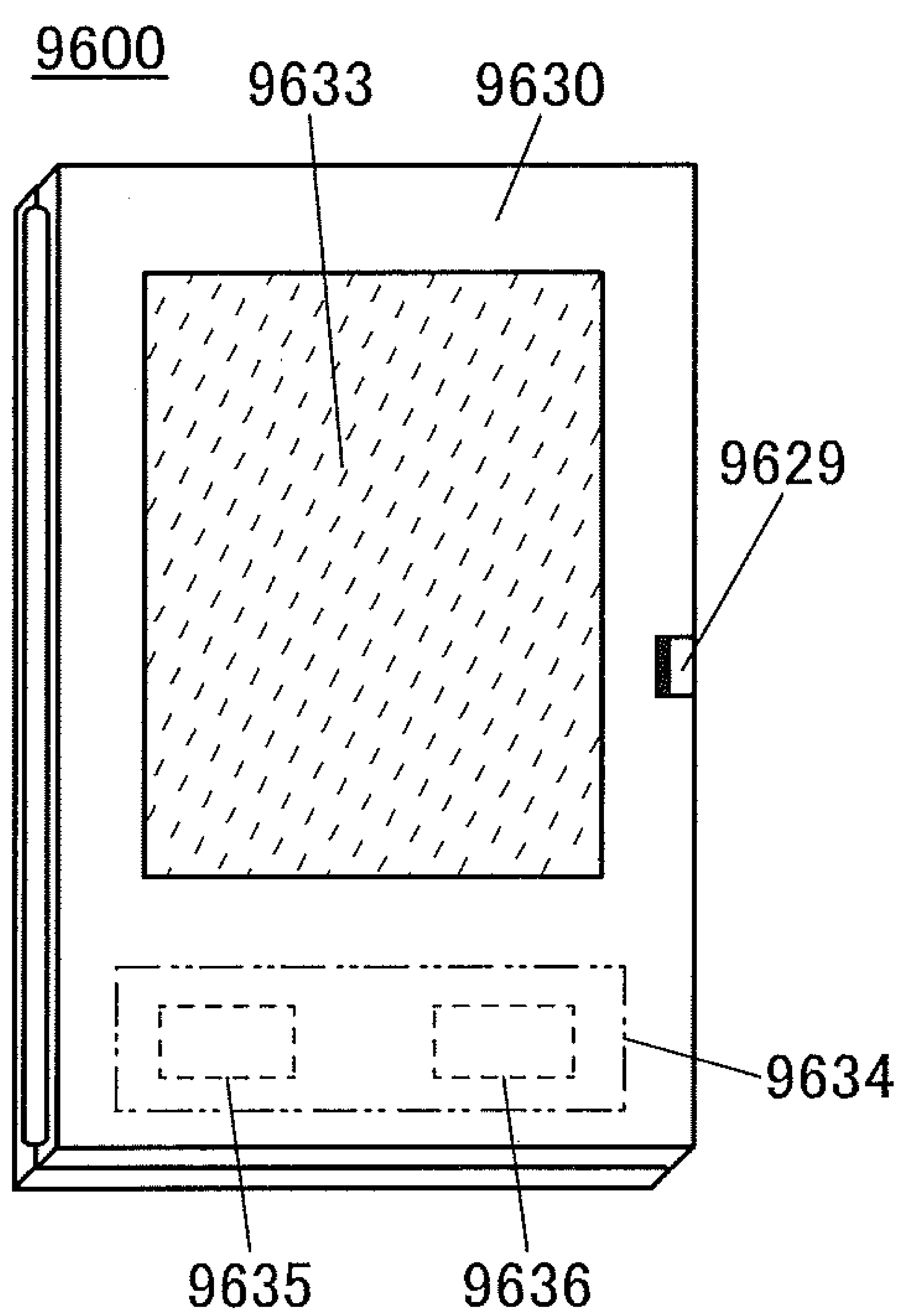


FIG. 54C

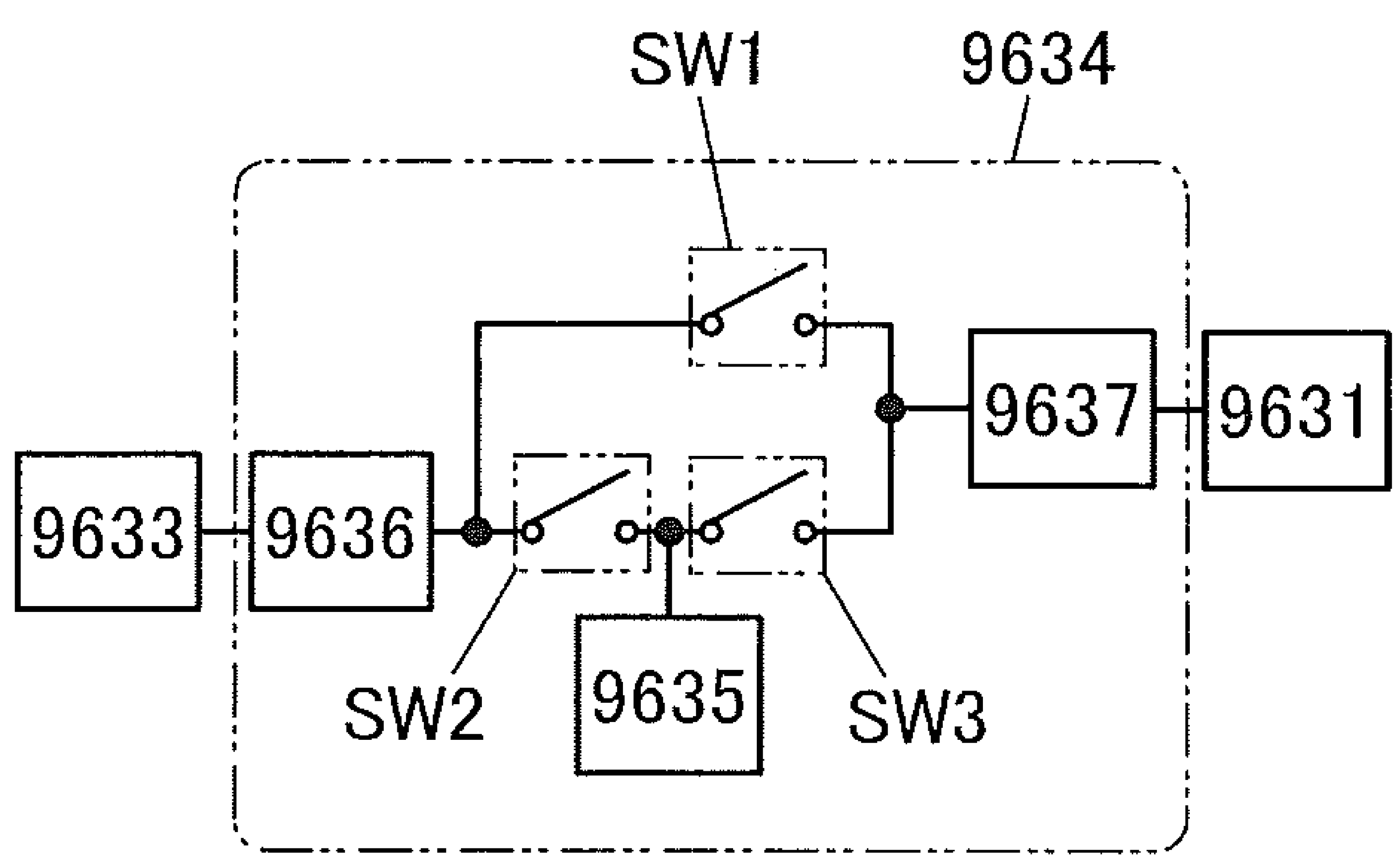


FIG. 55A

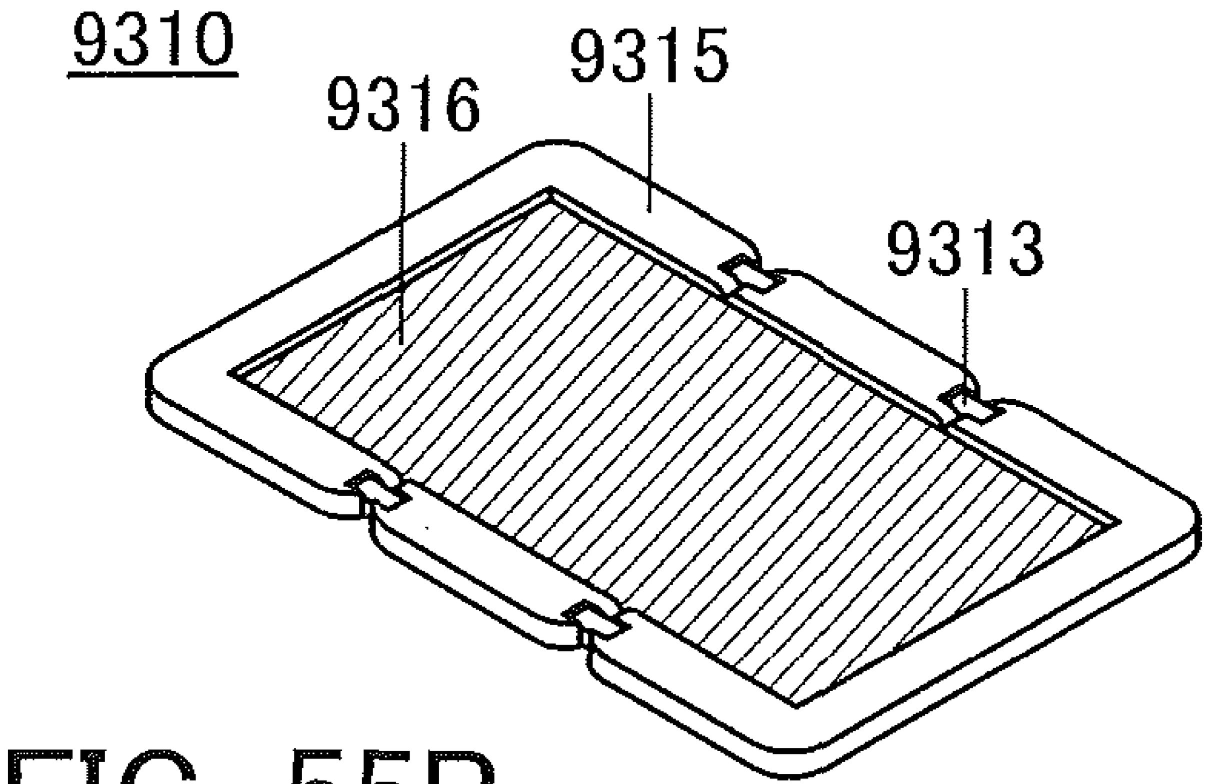


FIG. 55B

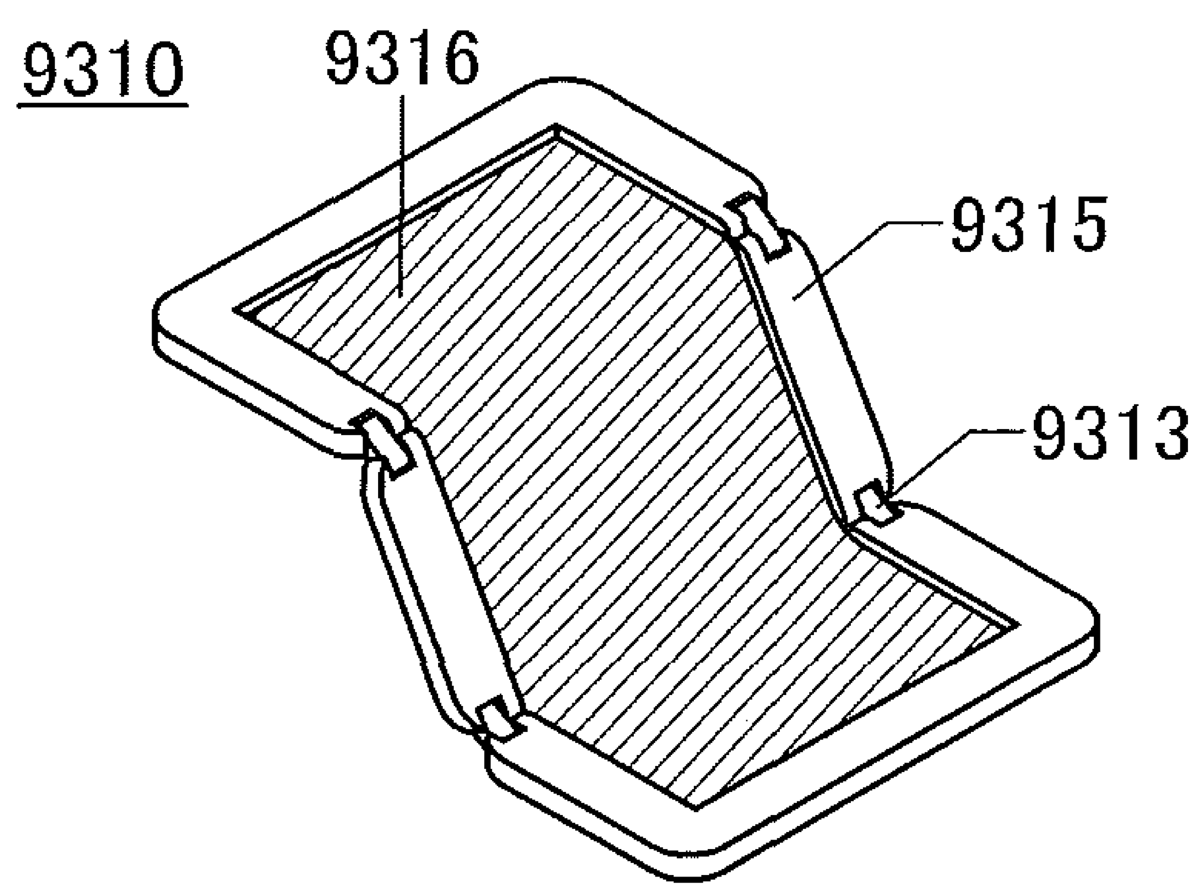


FIG. 55C

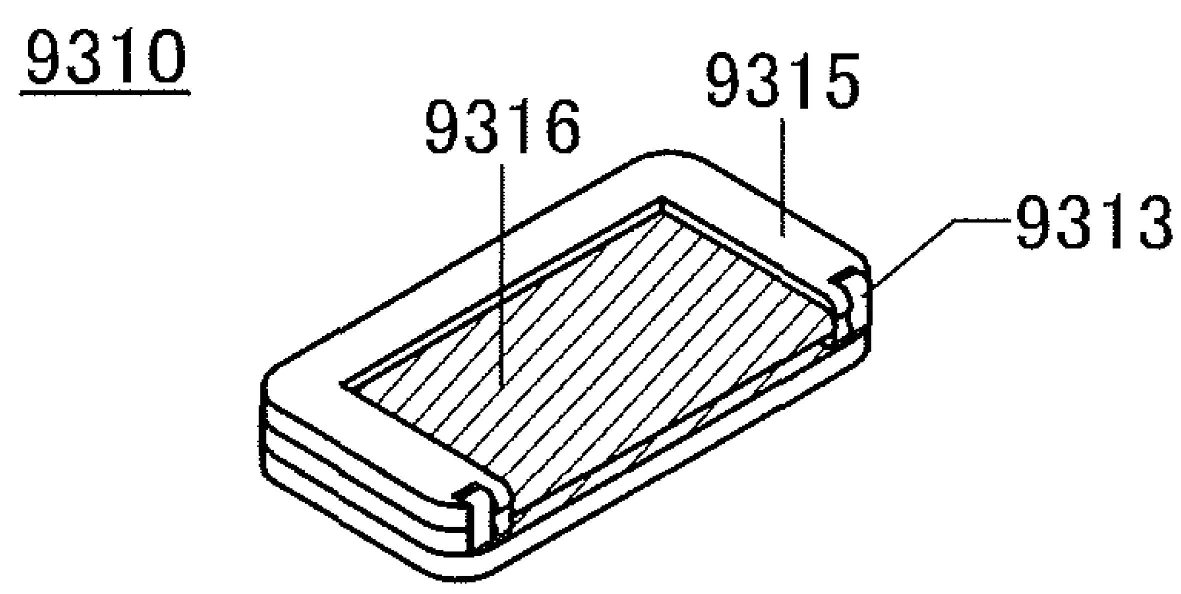


FIG. 55D

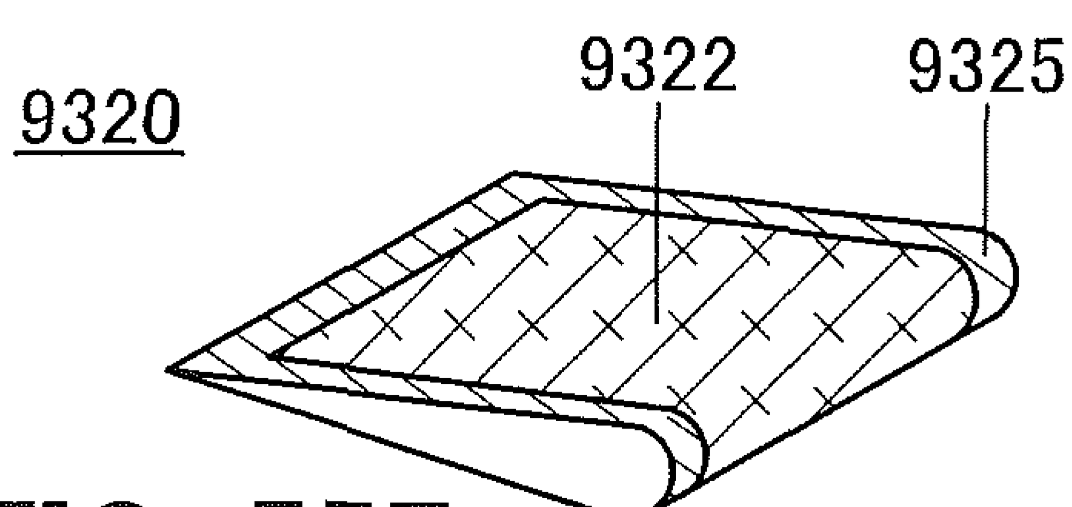


FIG. 55E

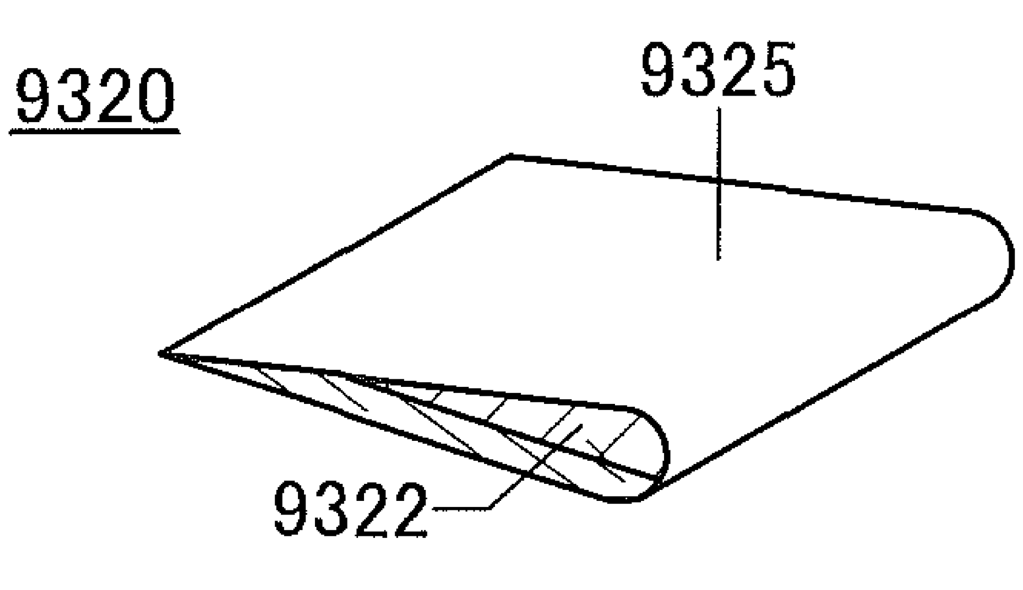


FIG. 55F

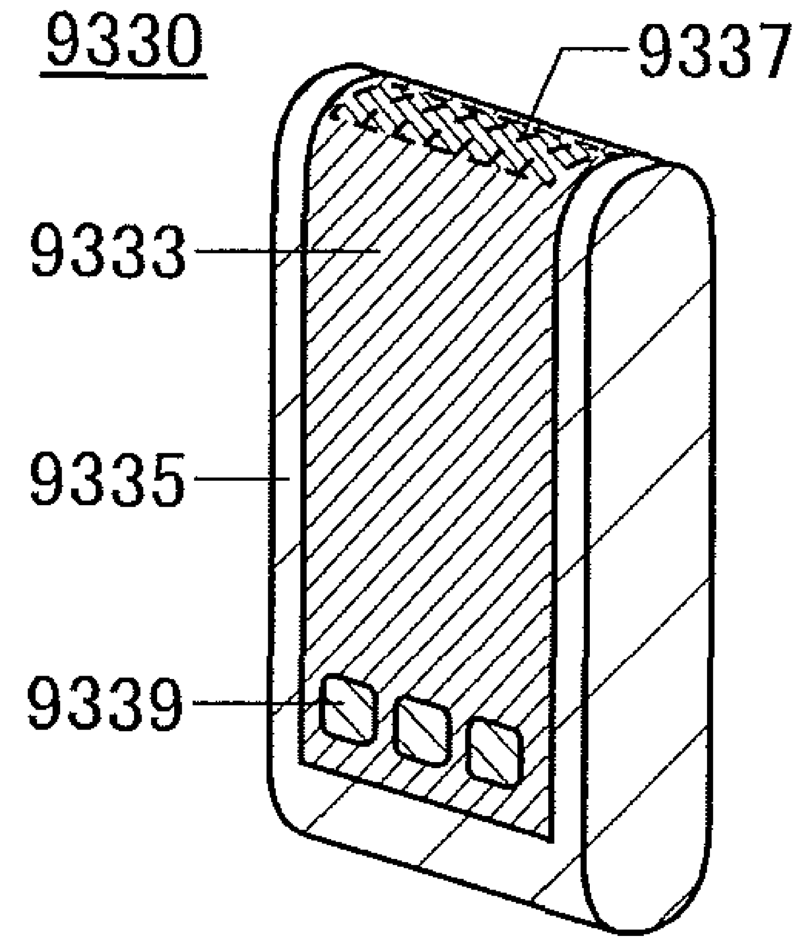


FIG. 55G

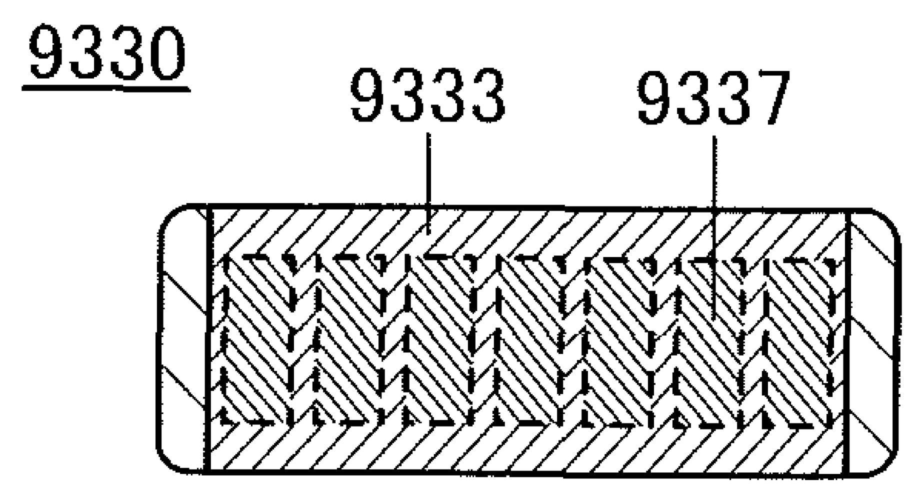


FIG. 55H

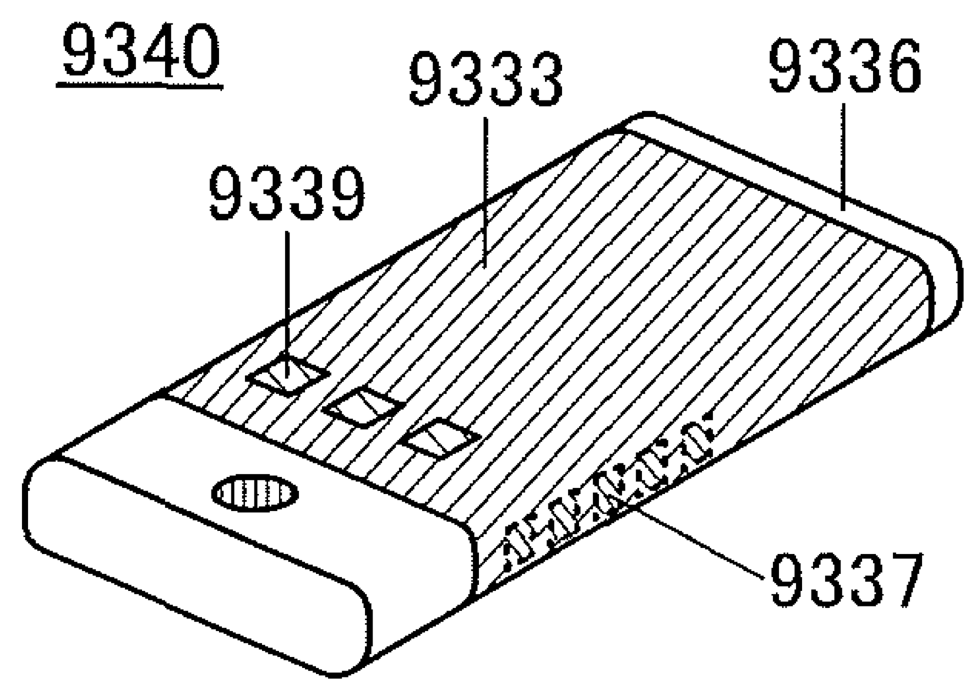


FIG. 55I

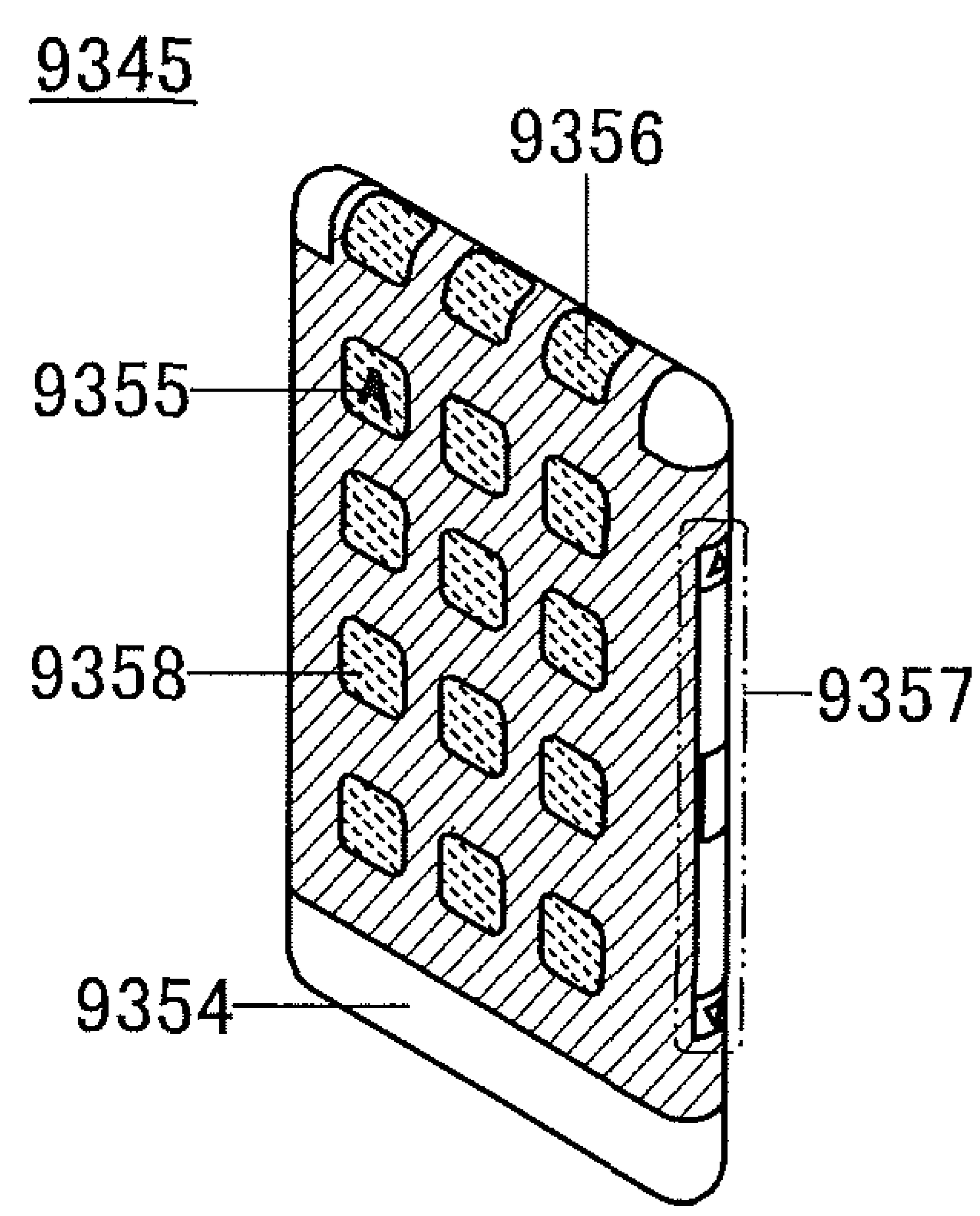


FIG. 56A

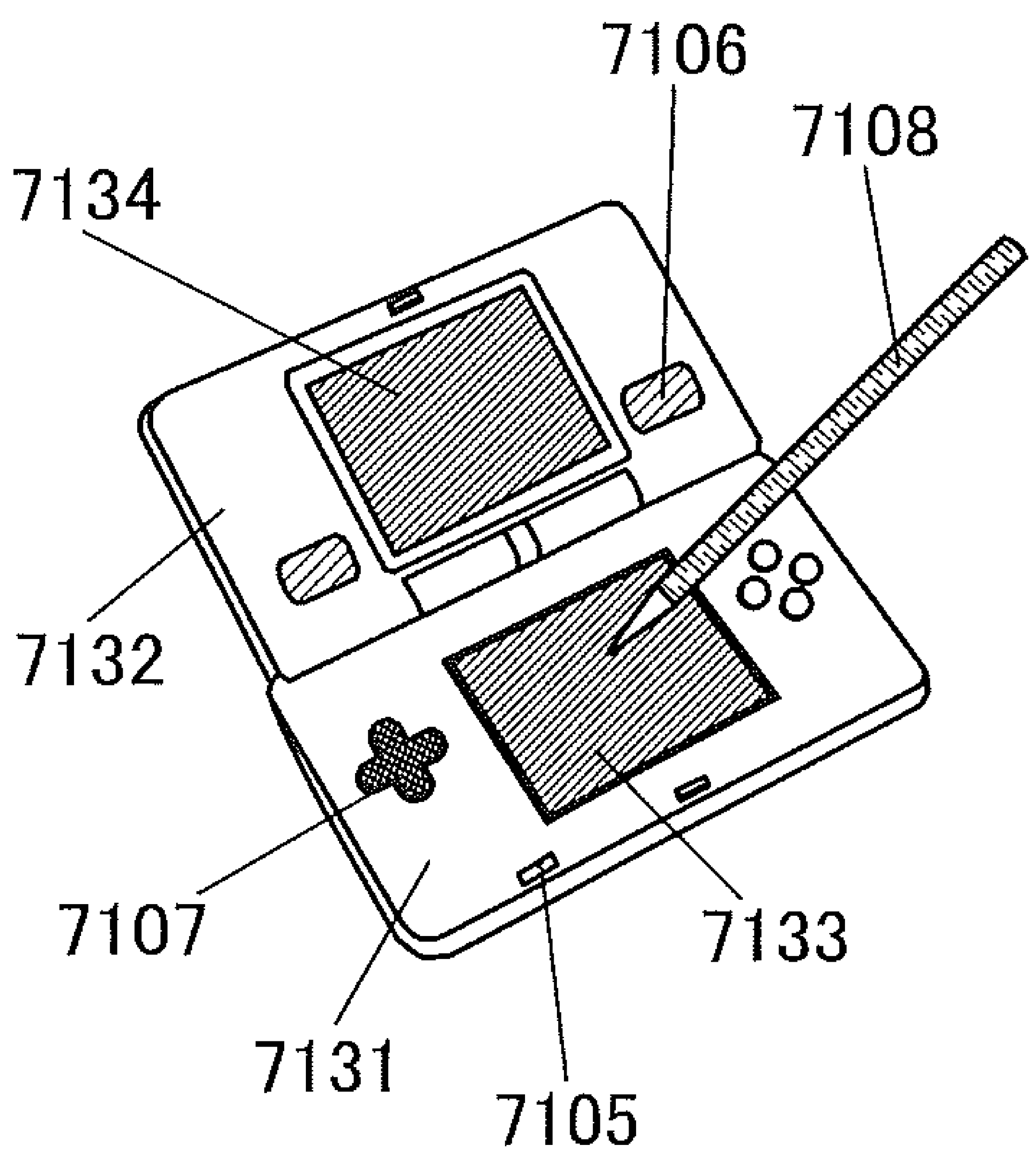


FIG. 56B

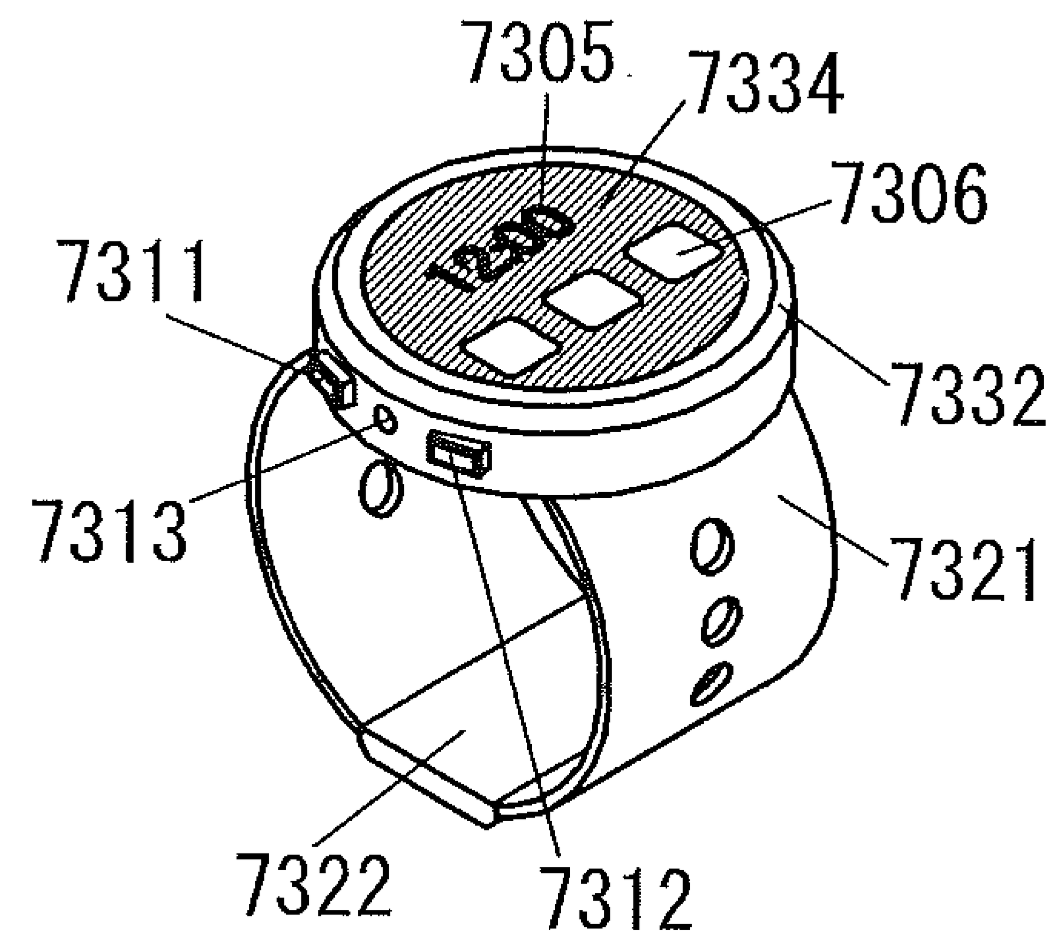


FIG. 56C

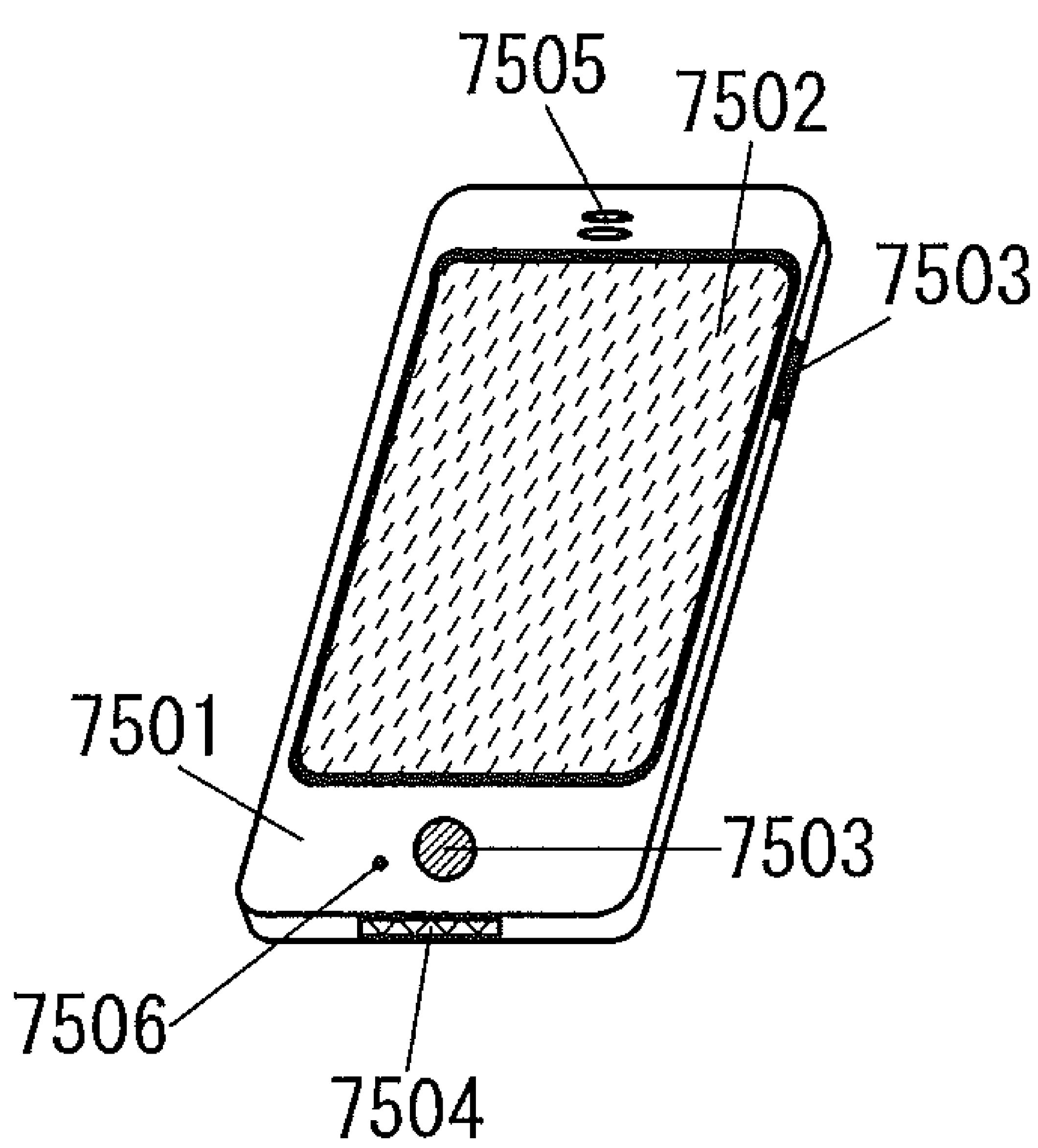


FIG. 56D

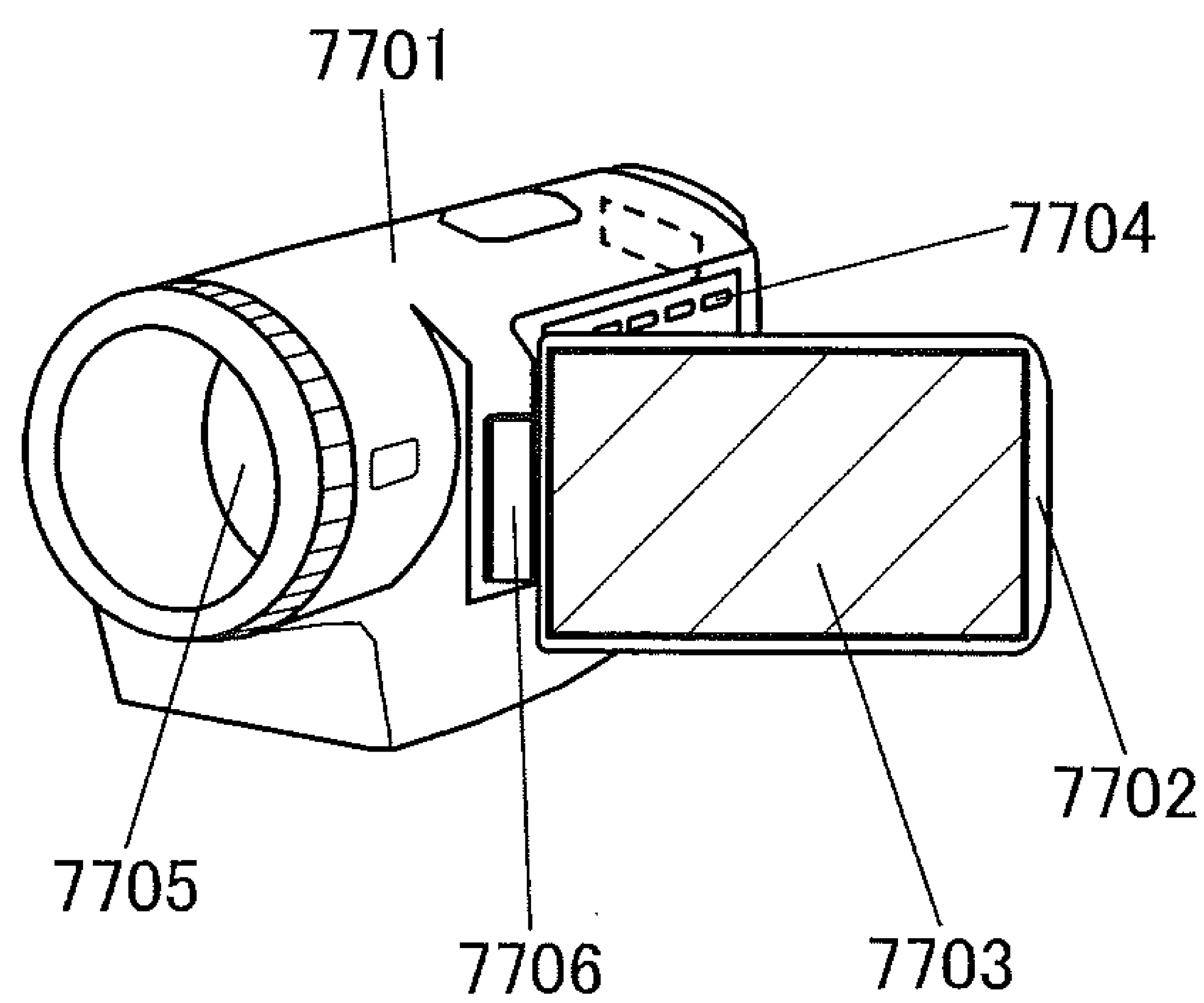


FIG. 57A

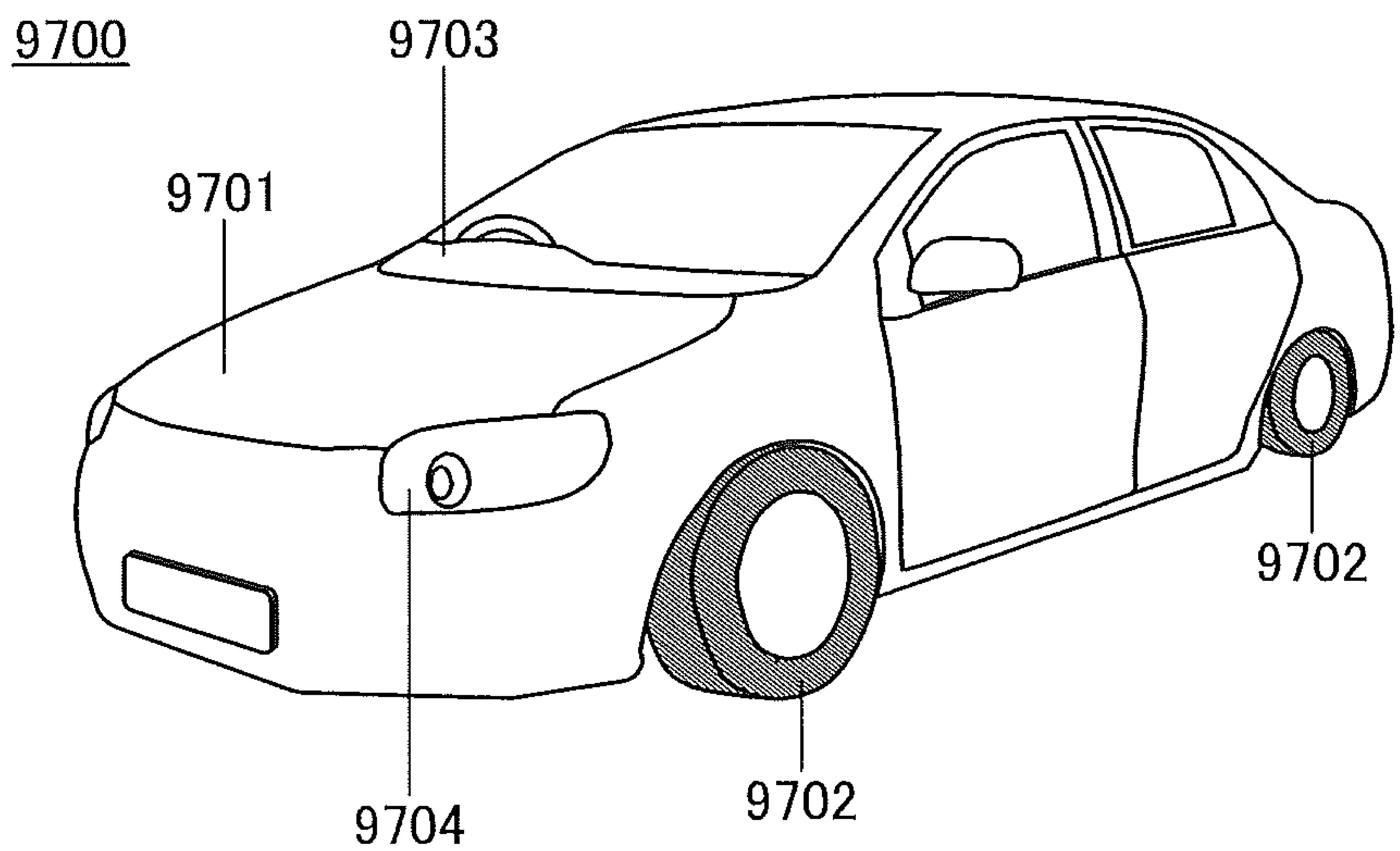


FIG. 57B

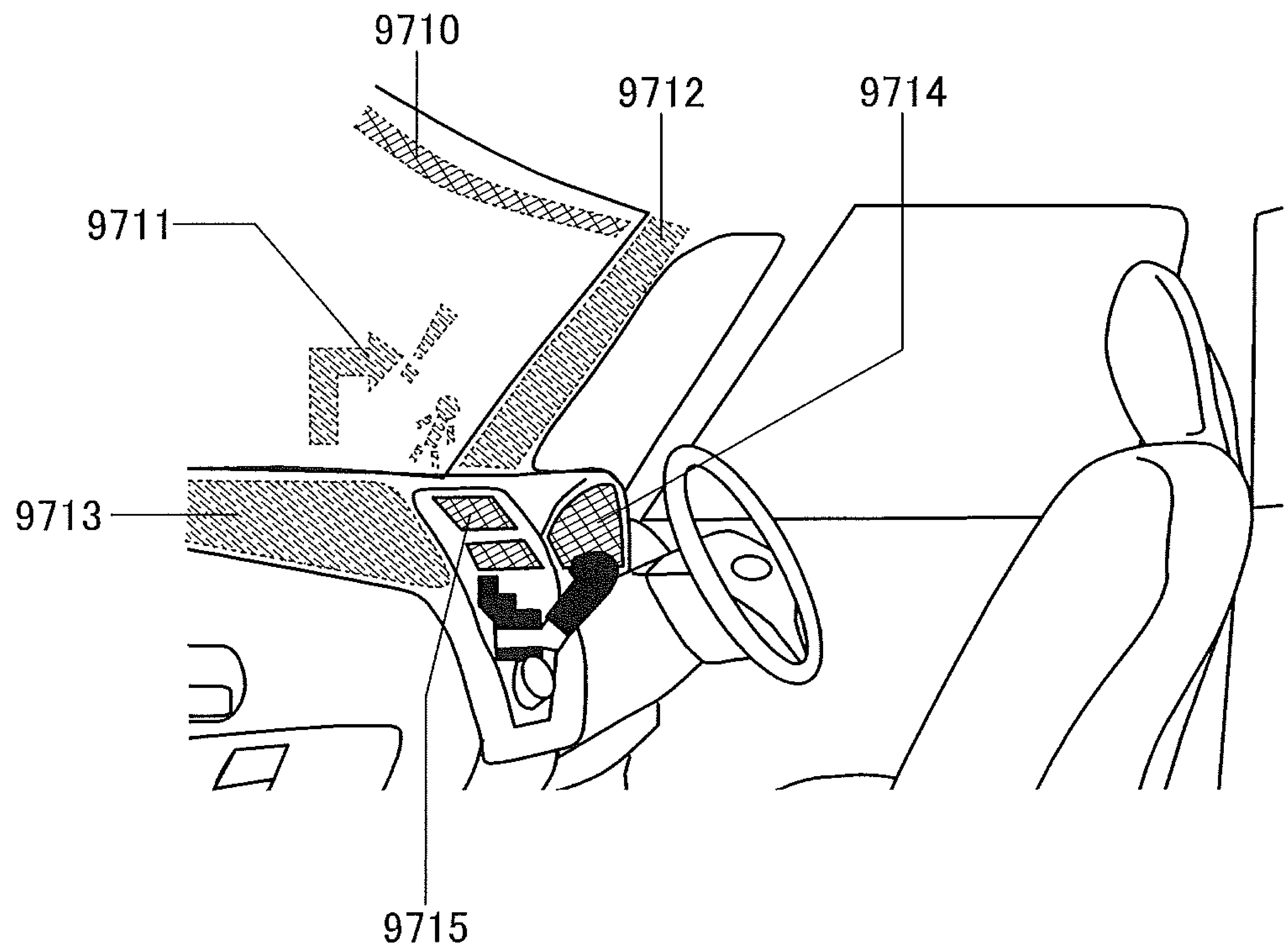
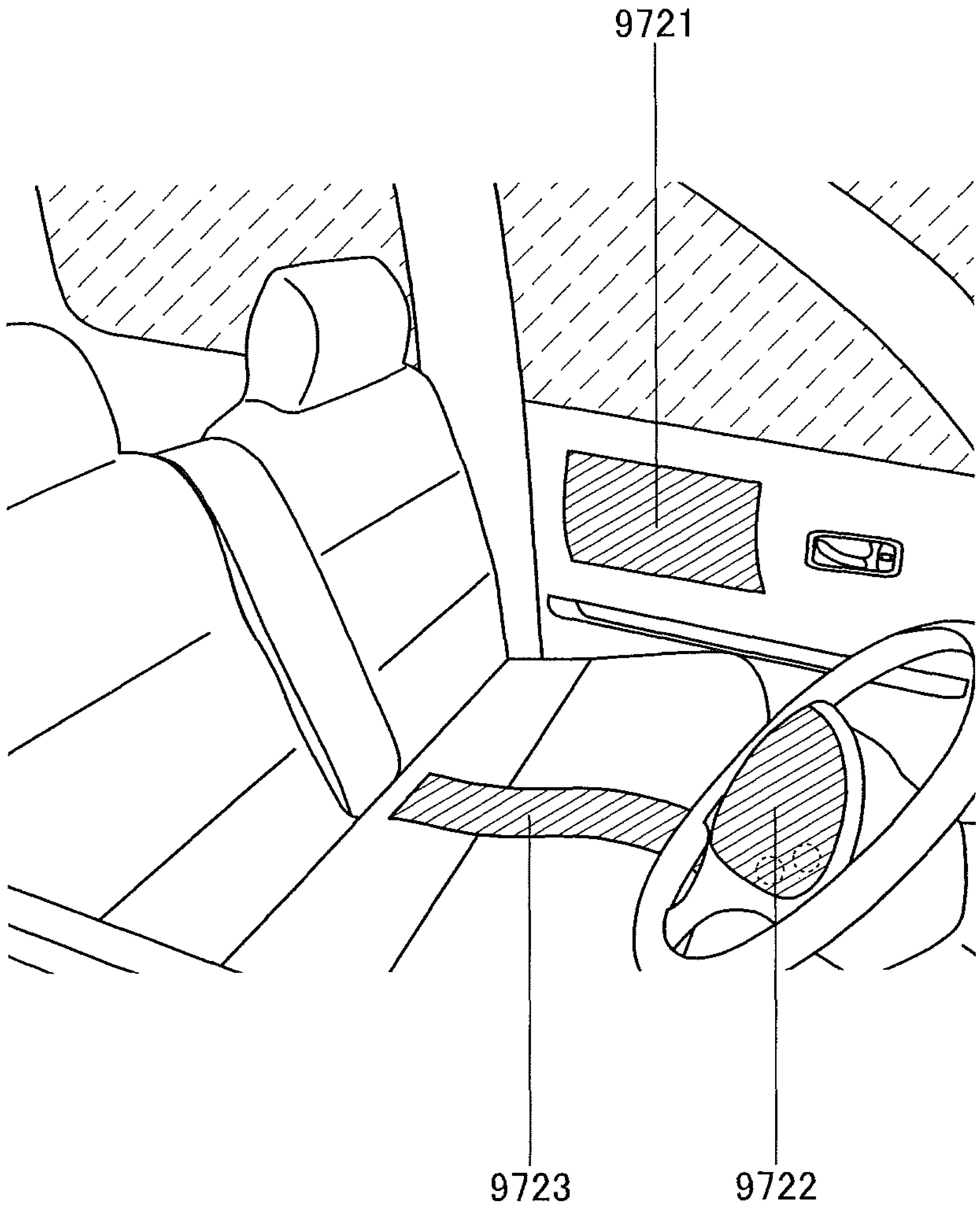


FIG. 58



DISPLAY DEVICE, MANUFACTURING METHOD THEREOF, AND ELECTRONIC DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

One embodiment of the present invention relates to a semiconductor device. One embodiment of the present invention also relates to a method for manufacturing the semiconductor device.

Note that one embodiment of the present invention is not limited to the above technical field. For example, one embodiment of the present invention relates to an object, a method, or a manufacturing method. One embodiment of the present invention relates to a process, a machine, manufacture, or a composition of matter.

Note that in this specification and the like, a semiconductor device generally means a device that can function by utilizing semiconductor characteristics. Thus, a semiconductor element such as a transistor or a diode and a semiconductor circuit are semiconductor devices. A display device, a light-emitting device, a lighting device, an electro-optical device, an imaging device, an electronic device, and the like may include a semiconductor element or a semiconductor circuit. Therefore, a display device, a light-emitting device, a lighting device, an electro-optical device, an imaging device, an electronic device, and the like include a semiconductor device in some cases.

2. Description of the Related Art

In recent years, research and development have been extensively conducted on liquid crystal elements as a display element used in a display region of a display device. In addition, research and development have been extensively conducted on light-emitting elements utilizing electroluminescence (EL). As a basic structure of these light-emitting elements, a layer containing a light-emitting substance is provided between a pair of electrodes. Voltage is applied to this light-emitting element to obtain light emission from the light-emitting substance.

Light-emitting elements are a self-luminous element; thus, a display device using the light-emitting elements has, in particular, advantages such as high visibility, no necessity of a backlight, and low power consumption. The display device using the light-emitting elements also has advantages in that it can be manufactured to be thin and lightweight and has high response speed.

A display device including the display elements can have flexibility; therefore, the use of a flexible substrate for the display device has been proposed.

As a method for manufacturing a display device using a flexible substrate, a technique is known in which a semiconductor element such as a thin film transistor is manufactured over a substrate such as a glass substrate or a quartz substrate, for example, the semiconductor element is fixed to another substrate (e.g., a flexible substrate) by using an organic resin, and then the semiconductor element is transferred from the glass substrate or the quartz substrate to the other substrate (Patent Document 1).

In addition, a technique for enhancing the mechanical strength of a display device by sandwiching an organic EL panel formed using a glass substrate with a thickness of greater than or equal to 20 μm and less than or equal to 50 μm between two flexible sheets is known (Patent Document 2).

Display devices are expected to be applied to a variety of uses and become diversified. For example, a smartphone and

a tablet terminal with a touch panel are being developed as portable information terminals.

REFERENCE

Patent Document

[Patent Document 1] Japanese Published Patent Application No. 2003-174153

[Patent Document 2] Japanese Published Patent Application No. 2010-244694

SUMMARY OF THE INVENTION

To protect a surface of a light-emitting element and prevent entry of impurity, such as moisture, from the outside, an additional substrate is attached to a light-emitting element formed over a substrate in some cases. However, there is a problem in that impurity such as moisture that enters from the outer periphery of the attached substrates (an edge of the substrates) contributes to a decrease in display quality and a decrease in reliability. To avoid this problem, the conventional display device needs a long distance from an edge of a substrate to a display region. As a result, a region that is outer than the display region and that does not contribute to display (hereinafter also referred to as frame) is wide, which inhibits an improvement in the productivity or the design flexibility of a display device and a semiconductor device including the display device.

Moreover, in the case where an organic EL panel is sandwiched between two flexible sheets as disclosed in Patent Document 2, impurity that enters an edge of the flexible sheets may cause a deterioration in display image or a decrease in reliability. In addition, in Patent Document 2, the flexible sheets are larger than the organic EL panel, which inevitably widens the frame including the flexible sheets.

An object of one embodiment of the present invention is to provide a highly reliable display device and a method for manufacturing the display device. Another object of one embodiment of the present invention is to provide a display device with high design flexibility and a method for manufacturing the display device.

Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like having high visibility. Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like having high display quality. Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like having high reliability. Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like that is unlikely to be broken. Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like with low power consumption. Another object of one embodiment of the present invention is to provide a display device, electronic device, or the like with high productivity. Another object of one embodiment of the present invention is to provide a novel display device, electronic device, or the like.

Note that the descriptions of these objects do not disturb the existence of other objects. In one embodiment of the present invention, there is no need to achieve all of these objects. Other objects will be apparent from and can be derived from the description of the specification, the drawings, the claims, and the like.

One embodiment of the present invention is a method for fabricating a display device including a first substrate having a first surface and a second surface, a second substrate having a third surface and a fourth surface, and a first layer. The method includes a first step of forming an element on at least one of the first surface and the third surface; a second step of overlapping the first substrate and the second substrate such that the first surface and the third surface face each other; a third step of putting a first filler into a depressed portion of a structure body and curing the first filler, thereby forming a second layer; a fourth step of disposing the second layer and one of the second surface and the fourth surface to face each other and disposing the first substrate and the second substrate on the second layer; a fifth step of separating the second layer, the first substrate, and the second substrate from the structure body; a sixth step of putting a second filler into the depressed portion of the structure body; a seventh step of disposing the second filler and the other of the second surface and the fourth surface to face each other and disposing the first substrate, the second substrate, and the second layer on the second filler; and an eighth step of curing the second filler, thereby forming the first layer in which the second filler and the second layer are bonded without a boundary.

Another embodiment of the present invention is a display device including a first substrate, a second substrate, and a first layer. The first substrate and the second substrate overlap each other with a display element positioned therebetween. The first layer covers the first substrate in a region where the first substrate and the second substrate overlap each other, the second substrate in a region where the first substrate and the second substrate overlap each other, and at least one of a side surface of the first substrate and a side surface of the second substrate.

The Young's modulus of the first layer is preferably smaller than the Young's modulus of each of the first substrate and the second substrate.

The Young's modulus of each of the first substrate and the second substrate is preferably larger than or equal to 1 GPa and smaller than or equal to 100 GPa.

The Young's modulus of the first layer is preferably smaller than or equal to one fiftieth of the Young's modulus of each of the first substrate and the second substrate.

At least one of the first substrate and the second substrate preferably has a light-transmitting property. The first layer preferably has a light-transmitting property. Examples of a material for the first layer include viscoelastic high molecular materials such as silicone rubber and fluorine rubber.

One embodiment of the present invention can provide a highly reliable display device and a manufacturing method thereof. Another embodiment of the present invention can provide a display device with high design flexibility and a manufacturing method thereof.

One embodiment of the present invention provides a display device, electronic device, or the like having high visibility. One embodiment of the present invention provides a display device, electronic device, or the like having high display quality. One embodiment of the present invention provides a display device, electronic device, or the like having high reliability. One embodiment of the present invention provides a display device, electronic device, or the like that is unlikely to be broken. One embodiment of the present invention provides a display device, electronic device, or the like with low power consumption. One embodiment of the present invention provides a display device, electronic device, or the like with high productivity. One embodiment of the present invention provides a novel display device, electronic device, or the like.

Note that the description of these effects does not disturb the existence of other effects. One embodiment of the present invention does not necessarily have all of these effects. Other effects will be apparent from and can be derived from the description of the specification, the drawings, the claims, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates one embodiment of a display device.

FIGS. **2**A to **2**C are a plan view and cross-sectional views illustrating one embodiment of a display device.

FIG. **3** is a cross-sectional view illustrating one embodiment of a display device.

FIGS. **4**A to **4**C are a block diagram and circuit diagrams illustrating embodiments of a display device.

FIGS. **5**A and **5**B are block diagrams illustrating embodiments of a display device.

FIGS. **6**A and **6**B each illustrate an example of a pixel configuration of one embodiment of a display device.

FIGS. **7**A and **7**B each illustrate an example of a pixel configuration of one embodiment of a display device.

FIGS. **8**A to **8**D are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **9**A to **9**D are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **10**A to **10**D are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **11**A and **11**B are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **12**A and **12**B are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **13**A and **13**B are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **14**A and **14**B are cross-sectional views illustrating an example of a method for fabricating a display device.

FIGS. **15**A and **15**B each illustrate one embodiment of a display device.

FIGS. **16**A to **16**C illustrate an example of a method for fabricating a display device.

FIG. **17** illustrates an example of a method for fabricating a display device.

FIGS. **18**A**1** and **18**A**2** and FIGS. **18**B**1** to **18**B**3** illustrate embodiments of a display device.

FIG. **19** is a cross-sectional view illustrating one embodiment of a display device.

FIGS. **20**A and **20**B are cross-sectional views illustrating one embodiment of a display device.

FIGS. **21**A and **21**B are cross-sectional views each illustrating one embodiment of a display device.

FIGS. **22**A and **22**B are cross-sectional views each illustrating one embodiment of a display device.

FIG. **23** is a cross-sectional view illustrating one embodiment of a display device.

FIG. **24** is a cross-sectional view illustrating one embodiment of a display device.

FIGS. **25**A to **25**E illustrate an example of a method for fabricating a display device.

FIGS. **26**A to **26**C each illustrate an example of a method for fabricating a display device.

FIGS. **27**A to **27**D illustrate an example of a method for fabricating a display device.

FIGS. **28**A and **28**B illustrate an example of a method for fabricating a display device.

FIGS. **29**A to **29**C illustrate examples of a method for fabricating a display device.

FIGS. **30**A and **30**B illustrate an example of a method for fabricating a display device.

FIGS. **31**A to **31**C illustrate an example of a structure body.

FIGS. **32**A to **32**C illustrate an example of a method for fabricating a display device.

FIG. **33** illustrates an example of a method for fabricating a display device.

FIGS. **34**A to **34**C illustrate an example of a method for fabricating a display device.

FIGS. **35**A and **35**B illustrate an example of a method for fabricating a display device.

FIG. **36** illustrates an example of a method for fabricating a display device.

FIGS. **37**A to **37**C illustrate an example of a method for fabricating a display device.

FIGS. **38**A and **38**B illustrate an example of a method for fabricating a display device.

FIGS. **39**A to **39**C illustrate an example of a structure body.

FIGS. **40**A to **40**C illustrate an example of a method for fabricating a display device.

FIG. **41** illustrates an example of a method for fabricating a display device.

FIGS. **42**A to **42**C illustrate an example of a method for fabricating a display device.

FIGS. **43**A to **43**C illustrate an example of a method for fabricating a display device.

FIGS. **44**A and **44**B illustrate an example of a method for fabricating a display device.

FIGS. **45**A**1**, **45**A**2**, **45**B**1**, and **45**B**2** each illustrate one embodiment of a transistor.

FIGS. **46**A**1**, **46**A**2**, **46**A**3**, **46**B**1**, and **46**B**2** each illustrate one embodiment of a transistor.

FIGS. **47**A to **47**C illustrate one embodiment of a transistor.

FIGS. **48**A to **48**C illustrate one embodiment of a transistor.

FIGS. **49**A to **49**C illustrate one embodiment of a transistor.

FIG. **50** illustrates an energy band structure.

FIGS. **51**A and **51**B each illustrate a structure example of a light-emitting element.

FIGS. **52**A to **52**F illustrate examples of electronic devices and lighting devices.

FIGS. **53**A and **53**B illustrate an example of an electronic device.

FIGS. **54**A to **54**C illustrate an example of an electronic device.

FIGS. **55**A to **55**I illustrate examples of electronic devices.

FIGS. **56**A to **56**D illustrate an example of an electronic device.

FIGS. **57**A and **57**B illustrate an example of an electronic device.

FIG. **58** illustrates examples of electronic devices.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments will be described in detail with reference to the accompanying drawings. Note that the present invention is not limited to the description below, and it is understood easily by those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention. Therefore, the present invention should not be construed as being limited to the description in the following embodiments. In the structures of the present invention to be described below, the same portions or portions having similar functions are denoted by the same reference numerals in different drawings, and explanation thereof will not be repeated.

The position, size, range, and the like of each component illustrated in the drawings and the like are not accurately represented in some cases to facilitate understanding of the invention. Therefore, the disclosed invention is not necessarily limited to the position, the size, range, and the like disclosed in the drawings and the like. For example, in the actual manufacturing process, a resist mask or the like might be unintentionally reduced in size by treatment such as etching, which might not be illustrated for easy understanding.

Especially in a top view (also referred to as a plan view), a perspective view, or the like, some components might not be illustrated for easy understanding.

In this specification and the like, the term such as an "electrode" or a "wiring" does not limit a function of a component. For example, an "electrode" is used as part of a "wiring" in some cases, and vice versa. Furthermore, the term "electrode" or "wiring" can also mean a combination of a plurality of "electrodes" and "wirings" formed in an integrated manner.

Note that the term "over" or "under" in this specification and the like does not necessarily mean that a component is placed "directly on" or "directly below" and "directly in contact with" another component. For example, the expression "electrode B over insulating layer A" does not necessarily mean that the electrode B is on and in direct contact with the insulating layer A and can mean the case where another component is provided between the insulating layer A and the electrode B.

Functions of a source and a drain might be switched depending on operation conditions, for example, when a transistor having opposite polarity is employed or the direction of current flow is changed in circuit operation. Thus, it is difficult to define which is a source or a drain. Accordingly, the terms "source" and "drain" can be switched in this specification.

Note that in this specification and the like, the expression "electrically connected" includes the case where components are connected through an "object having any electric function". There is no particular limitation on an "object having any electric function" as long as electric signals can be transmitted and received between components that are connected through the object. Accordingly, even when the expression "electrically connected" is used in this specification, there is a case in which no physical connection is made and a wiring is just extended in an actual circuit.

In this specification and the like, a term "parallel" indicates that, for example, the angle formed between two straight lines is greater than or equal to −10° and less than or equal to 10°, and accordingly also includes the case where the angle is greater than or equal to −5° and less than or equal to 5°. A term "perpendicular" indicates that, for example, the angle formed between two straight lines is greater than or equal to 80° and less than or equal to 100°, and accordingly also includes the case where the angle is greater than or equal to 85° and less than or equal to 95°.

In the specification and the like, the terms "identical", "the same", "equal", "uniform", and the like used in describing calculation values and actual measurement values allow for a margin of error of ±20% unless otherwise specified.

In this specification, in the case where an etching step is performed after a lithography process, a resist mask formed in the lithography process is removed after the etching step, unless otherwise specified.

A voltage usually refers to a potential difference between a given potential and a reference potential (e.g., a source potential or a ground potential (a GND potential)). A voltage can be referred to as a potential and vice versa.

Note that an impurity in a semiconductor refers to, for example, elements other than the main components of the semiconductor. For example, an element with a concentration lower than 0.1 atomic % can be regarded as an impurity. When an impurity is contained, the density of states (DOS) in a semiconductor may be increased, the carrier mobility may be decreased, or the crystallinity may be decreased, for example. In the case where the semiconductor is an oxide semiconductor, examples of an impurity which changes characteristics of the semiconductor include Group 1 elements, Group 2 elements, Group 13 elements, Group 14 elements, Group 15 elements, and transition metals other than the main components of the oxide semiconductor; specifically, there are hydrogen (included in water), lithium, sodium, silicon, boron, phosphorus, carbon, and nitrogen, for example. In the case of an oxide semiconductor, oxygen vacancies may be formed by entry of impurities such as hydrogen. In the case where the semiconductor is silicon, examples of an impurity which changes characteristics of the semiconductor include oxygen, Group 1 elements except hydrogen, Group 2 elements, Group 13 elements, and Group 15 elements.

Note that ordinal numbers such as "first" and "second" in this specification and the like are used in order to avoid confusion among components and do not denote the priority or the order such as the order of steps or the stacking order. A term without an ordinal number in this specification and the like might be provided with an ordinal number in a claim in order to avoid confusion among components. A term with an ordinal number in this specification and the like might be provided with a different ordinal number in a claim. Moreover, a term with an ordinal number in this specification and the like might not be provided with any ordinal number in a claim.

Note that in this specification, the channel length refers to, for example, a distance, observed in a top view of a transistor, between a source (a source region or a source electrode) and a drain (a drain region or a drain electrode) in a region where a semiconductor and a gate electrode overlap with each other, a portion where a current flows in a semiconductor when the transistor is on, or a region where a channel is formed. In one transistor, channel lengths are not necessarily the same in all regions. In other words, the channel length of one transistor is not limited to one value in some cases. Therefore, in this specification, the channel length is any one of values, the maximum value, the minimum value, or the average value in a region where a channel is formed.

Note that in this specification and the like, an "on state" of a transistor refers to a state in which a source and a drain of the transistor are electrically short-circuited. Furthermore, an "off state" of the transistor refers to a state in which the source and the drain of the transistor are electrically disconnected.

In this specification and the like, in some cases, "on-state current" means a current which flows between a source and a drain when a transistor is on, and "off-state current" means a current which flows between a source and a drain when a transistor is off.

The off-state current of a transistor depends on a voltage between a gate and a source (also referred to as Vgs) in some cases. Thus, "the off-state current of a transistor is lower than or equal to I" means "there is Vgs with which the off-state current of the transistor becomes lower than or equal to I" in some cases. The off-state current of a transistor may refer to a current at a certain Vgs or a current at Vgs in a certain voltage range.

As an example, the assumption is made of an n-channel transistor where the threshold voltage Vth is 0.5 V and the current flowing between a source and a drain (hereinafter also referred to as Ids) is 1×10^{-9} A at Vgs of 0.5 V, 1×10^{-13} A at Vgs of 0.1 V, 1×10^{-19} A at Vgs of −0.5 V, and 1×10^{-22} A at Vgs of −0.8 V. The Ids of the transistor is 1×10^{-9} A or lower at Vgs of −0.5 V or at Vgs in the range of −0.8 V to −0.5 V; therefore, it can be said that the off-state current of the transistor is 1×10^{-19} A or lower. Since there is Vgs at which the drain current of the transistor is 1×10^{-22} A or lower, it can be said that the off-state current of the transistor is 1×10^{-22} A or lower.

The off-state current of a transistor depends on temperature in some cases. Unless otherwise specified, the off-state current in this specification may be an off-state current at room temperature, 60° C., 85° C., 95° C., or 125° C. Alternatively, the off-state current may be an off-state current at a temperature at which the reliability of a semiconductor device or the like including the transistor is ensured or a temperature at which the semiconductor device or the like is used (e.g., temperature in the range of 5° C. to 35° C.). When there is Vgs at which the off-state current of a transistor at room temperature, 60° C., 85° C., 95° C., 125° C., a temperature at which the reliability of a semiconductor device or the like including the transistor is ensured, or a temperature at which the semiconductor device or the like is used (e.g., temperature in the range of 5° C. to 35° C.) is lower than or equal to I, it may be said that the off-state current of the transistor is lower than or equal to I.

The off-state current of a transistor depends on voltage between its drain and source (hereinafter also referred to as Vds) in some cases. Unless otherwise specified, the off-state current in this specification may be an off-state current at Vds with an absolute value of 0.1 V, 0.8 V, 1 V, 1.2 V, 1.8 V, 2.5 V, 3 V, 3.3 V, 10 V, 12 V, 16 V, or 20 V. Alternatively, the off-state current may be an off-state current at Vds at which the reliability of a semiconductor device or the like including the transistor is ensured or Vds used in the semiconductor device or the like.

The channel width refers to, for example, the length of a portion where a source and a drain face each other in a region where a semiconductor and a gate electrode overlap with each other, a portion where a current flows in a semiconductor when a transistor is on, or a region where a channel is formed. In one transistor, channel widths are not necessarily the same in all regions. In other words, the channel width of one transistor is not limited to one value in some cases. Therefore, in this specification, a channel width is any one of values, the maximum value, the minimum value, or the average value in a region where a channel is formed.

Note that depending on transistor structures, a channel width in a region where a channel is formed actually (hereinafter referred to as an effective channel width) is different from a channel width shown in a top view of a transistor (hereinafter referred to as an apparent channel width) in some cases. For example, in a transistor having a gate electrode covering a side surface of a semiconductor, an effective channel width is greater than an apparent channel width, and its influence cannot be ignored in some cases. For example, in a miniaturized transistor having a gate electrode covering a side surface of a semiconductor, the proportion of a channel region formed in a side surface of a semiconductor is higher than the proportion of a channel region formed in a top surface of a semiconductor in some cases. In that case, an effective channel width is greater than an apparent channel width.

In such a case, an effective channel width is difficult to measure in some cases. For example, to estimate an effective channel width from a design value, it is necessary to assume that the shape of a semiconductor is known as an assumption condition. Therefore, in the case where the shape of a semiconductor is not known accurately, it is difficult to measure an effective channel width accurately.

Therefore, in this specification, an apparent channel width is referred to as a surrounded channel width (SCW) in some cases. Furthermore, in this specification, in the case where the term "channel width" is simply used, it may denote a surrounded channel width and an apparent channel width. Alternatively, in this specification, in the case where the term "channel width" is simply used, it may denote an effective channel width in some cases. Note that a channel length, a channel width, an effective channel width, an apparent channel width, a surrounded channel width, and the like can be determined by analyzing a cross-sectional TEM image and the like.

Note that in the case where electric field mobility, a current value per channel width, and the like of a transistor are calculated, a surrounded channel width might be used for the calculation. In that case, a value might be different from one calculated by using an effective channel width.

Embodiment 1

A structure example of a display device **100** of one embodiment of the present invention is described with reference to FIG. **1**, FIGS. **2**A to **2**C, FIG. **3**, FIGS. **4**A to **4**C, FIGS. **5**A and **5**B, FIGS. **6**A and **6**B, and FIGS. **7**A and **7**B. Note that the display device **100** disclosed in this specification is a display device in which a light-emitting element is used as a display element. As the display device **100** of one embodiment of the present invention, a display device having a top-emission structure is described as an example. Note that the display device **100** of one embodiment of the present invention can be a display device having a bottom-emission structure or a dual-emission structure.

<Structure of Display Device>

FIG. **1** is a perspective view of the display device **100** to which an external electrode **124** is connected and which is covered with the layer **147**. FIG. **2**A is a plan view of the light-emitting device **100**. FIG. **2**B is a cross-sectional view taken along the dashed-dotted line V**1**-V**2** in FIG. **2**A. FIG. **2**C is a cross-sectional view taken along the dashed-dotted line H**1**-H**2** in FIG. **2**A. FIG. **3** is a detailed cross-sectional view taken along the dashed-dotted line A**1**-A**2** in FIG. **1**. Note that FIG. **3** more specifically illustrates part of the cross section in FIG. **2**C.

The display device **100** described in this embodiment includes a display region **131**, a circuit **132**, and a circuit **133**. The display device **100** also includes a terminal electrode **216** and a light-emitting element **125** including an electrode **115**, an EL layer **117**, and an electrode **118**. A plurality of light-emitting elements **125** are formed in the display region **131**. A transistor **232** for controlling the amount of light emitted from the light-emitting element **125** is connected to each of the light-emitting elements **125**.

The external electrode **124** and the terminal electrode **216** are electrically connected to each other through an anisotropic conductive connection layer **123**. A part of the terminal electrode **216** is electrically connected to the circuit **132**, and another part of the terminal electrode **216** is electrically connected to the circuit **133**.

The circuit **132** and the circuit **133** each include a plurality of transistors **252**. The circuit **132** and the circuit **133** each have a function of determining which of the light-emitting elements **125** in the display region **131** is supplied with a signal through the external electrode **124**.

The transistor **232** and the transistor **252** each include a gate electrode **206**, a gate insulating layer **207**, a semiconductor layer **208**, a source electrode **209***a*, and a drain electrode **209***b*. A wiring **219** is formed in the same layer where the source electrode **209***a* and the drain electrode **209***b* are formed. In addition, an insulating layer **210** is formed over the transistor **232** and the transistor **252**, and an insulating layer **211** is formed over the insulating layer **210**. The electrode **115** is formed over the insulating layer **211**. The electrode **115** is electrically connected to the drain electrode **209***b* through an opening formed in the insulating layer **210** and the insulating layer **211**. A partition **114** is formed over the electrode **115**, and the EL layer **117** and the electrode **118** are formed over the electrode **115** and the partition **114**.

In the display device **100**, a substrate **111** and a substrate **121** are attached to each other with a bonding layer **120** provided therebetween.

One surface of the substrate **111** is provided with an insulating layer **205** with a bonding layer **112** positioned therebetween. One surface of the substrate **121** is provided with an insulating layer **145** with a bonding layer **142** positioned therebetween. The one surface of the substrate **121** is provided with a light-blocking layer **264** with the insulating layer **145** positioned therebetween. The one surface of the substrate **121** is also provided with a coloring layer **266** and an overcoat layer **268** with the insulating layer **145** positioned therebetween.

The insulating layer **205** functions as a base layer and can prevent or reduce diffusion of moisture or impurity elements from the substrate **111**, the bonding layer **112**, or the like to the transistor or the light-emitting element. The insulating layer **145** functions as a base layer and can prevent or reduce diffusion of moisture or impurity elements from the substrate **121**, the bonding layer **142**, or the like to the transistor or the light-emitting element.

The insulating layer **205** and the insulating layer **145** are preferably formed as a single layer or a multilayer using any of silicon oxide, silicon nitride, silicon oxynitride, silicon nitride oxide, aluminum oxide, aluminum oxynitride, and aluminum nitride oxide. The insulating layer **205** and the insulating layer **145** can be formed by a sputtering method, a CVD method, a thermal oxidation method, a coating method, a printing method, or the like.

For example, a flexible material such as an organic resin material can be used for the substrate **111** and the substrate **121**. In the case where the display device **100** has a bottom-emission structure or a dual-emission structure, a material having a light-transmitting property with respect to light emitted from the EL layer **117** is used for the substrate **111**. In the case where the display device **100** has a top-emission structure or a dual-emission structure, a material having a light-transmitting property with respect to light emitted from the EL layer **117** is used for the substrate **121**.

If the mechanical strength of a material used for the substrate **111** and the substrate **121** is too low, the substrates easily become deformed at the time of manufacture of the display device **100**, which reduces yield and thus, contributes to a reduction in productivity. Yet, if the mechanical strength of the material used for the substrate **111** and the substrate **121** is too high, the display device becomes difficult to bend. An index of the mechanical strength of a material is a Young's modulus. The Young's modulus of a material suitable for the substrate **111** and the substrate **121** is larger than or equal to 1 GPa (1×10^9 Pa) and smaller than or equal to 100 GPa (100×10^9 Pa), preferably larger than or equal to 2 GPa and smaller than or equal to 50 GPa, further preferably larger than or equal to 2 GPa and smaller than or equal to 20 GPa. Note that in measurement of a Young's modulus, ISO527, JISK7161, JISK7162, JISK7127, ASTMD638, ASTMD882, or the like can be referred to.

The thickness of each of the substrate **111** and the substrate **121** is preferably greater than or equal to 5 μm and less than or equal to 100 μm, further preferably greater than or equal to 10 μm and less than or equal to 50 μm. One or both of the substrate **111** and the substrate **121** may be a stacked-layer substrate that includes a plurality of layers.

It is preferable that the substrate **111** and the substrate **121** be formed using the same material and have the same thickness. However, depending on the purpose, the substrates **111** and **121** may be formed using different materials or have different thicknesses.

Examples of materials that have flexibility and transmit visible light, which can be used for the substrate **111** and the substrate **121**, include a polyethylene terephthalate resin, a polyethylene naphthalate resin, a polyacrylonitrile resin, a polyimide resin, a polymethylmethacrylate resin, a polycarbonate resin, a polyethersulfone resin, a polyamide resin, a cycloolefin resin, a polystyrene resin, a polyamide imide resin, a polyvinylchloride resin, and polytetrafluoroethylene (PTFE). Furthermore, when a light-transmitting property is not necessary, a non-light-transmitting substrate may be used. For example, aluminum or the like may be used for the substrate **121** or the substrate **111**.

The thermal expansion coefficients of the substrate **111** and the substrate **121** are preferably less than or equal to 30 ppm/K, more preferably less than or equal to 10 ppm/K. In addition, on surfaces of the substrate **111** and the substrate **121**, a protective film having low water permeability may be formed in advance; examples of the protective film include a film containing nitrogen and silicon such as a silicon nitride film or a silicon oxynitride film and a film containing nitrogen and aluminum such as an aluminum nitride film. Note that a structure in which a fibrous body is impregnated with an organic resin (also called prepreg) may be used as the substrate **111** and the substrate **121**.

With such substrates, a non-breakable display device can be provided. Alternatively, a lightweight display device can be provided. Alternatively, an easily bendable display device can be provided.

For the layer **147**, a material that is more flexible than the substrates **111** and **121** is used. For example, a material having a smaller Young's modulus than the substrate **111** is used for the layer **147**.

The Young's modulus of the material used for the layer **147** is preferably smaller than or equal to one fiftieth, further preferably smaller than or equal to one hundredth, still further preferably smaller than or equal to one five hundredth of the Young's modulus of the materials used for the substrates **111** and **121**.

Examples of a material that can be used for the layer **147** include a viscoelastic high molecular material such as silicone rubber or fluorine rubber. The material used for the layer **147** preferably has a light-transmitting property.

A material with a small Young's modulus more easily becomes deformed than a material with a large Young's modulus does; therefore, internal stress generated by deformation is easily dispersed in the former. When a material with a Young's modulus smaller than that of the substrate **111** and the substrate **121** is used for the layer **147**, local stress generated in the substrate **111** and the substrate **121** at the time of bending can be relaxed, whereby the substrate **111** and the substrate **121** can be prevented from being broken. The layer **147** also functions as a buffer dispersing external physical pressure and impact.

The layer **147** can prevent the minimum radius of curvature of a bent portion from being smaller than the thickness of the layer **147**. Therefore, breakage of the substrate **111** or the substrate **121** due to bending at an excessively small radius of curvature can be prevented.

In one embodiment of the present invention, the display device **100** can be prevented from being broken even when the minimum curvature radius of the substrate **111** or **121** that is positioned on the inner side of a bent portion is 1 mm or less.

The thickness of the layer **147** is preferably greater than or equal to 2 times and less than or equal to 100 times that of the substrate **111** and the substrate **121**, further preferably greater than or equal to 5 times and less than or equal to 50 times that of the substrate **121**. When the layer **147** is thicker than the substrate **111** and the substrate **121**, stress relaxation and the effect of buffers can be enhanced.

Depending on the usage of the display device, the layer **147** may have a stacked structure formed of a plurality of layers.

A thickness t**1** of the layer **147** formed on the substrate **111** side is preferably equal to a thickness t**2** of the layer **147** formed on the substrate **121** side. When the thickness t**1** is the same as the thickness t**2**, the display device **100** can be disposed in the neutral plane. By disposing the display device **100** in the neutral plane, damage to the display device **100** which is caused by compressive stress or tensile stress applied to the layer **147** at a bend portion can be reduced. Therefore, the display device **100** can have higher reliability.

In one embodiment of the present invention, a display device that is resistant to external impact and unlikely to be broken can be provided.

In one embodiment of the present invention, a highly reliable display device can be provided which is unlikely to be broken even when it is repeatedly bent and stretched.

The layer **147** that covers the edges (a side surfaces) of the substrate **111** and the substrate **121** can prevent entry of impurity such as moisture from the edges. Therefore, the display device **100** can have high reliability and high display quality even when the frame of the display device **100** is narrowed. In one embodiment of the present invention, the productivity and design flexibility of the display device **100** can be improved. Furthermore, the productivity and design flexibility of a semiconductor device including the display device of one embodiment of the present invention can be improved.

[Example of Pixel Circuit Configuration]

Next, an example of a specific configuration of the display device **100** is described with reference to FIGS. **4**A to **4**C. FIG. **4**A is a block diagram illustrating the configuration of the display device **100**. The display device **100** includes the display region **131**, the circuit **132**, and the circuit **133**. The circuit **132** functions as a scan line driver circuit, for example, and the circuit **133** functions as a signal line driver circuit, for example.

The display device **100** includes in scan lines **135** which are arranged parallel or substantially parallel to each other and whose potentials are controlled by the circuit **132**, and n signal lines **136** which are arranged parallel or substantially parallel to each other and whose potentials are controlled by the circuit **133**. The display region **131** includes a plurality of pixels **130** arranged in a matrix of m rows by n columns. Note that nm and n are each a natural number of 2 or more.

Each of the scan lines **135** is electrically connected to the n pixels **130** in the corresponding row among the pixels **130** arranged in the display region **131**. Each of the signal lines **136** is electrically connected to the nm pixels **130** in the corresponding column among the pixels **130**.

As illustrated in FIG. **5**A, a circuit **152** may be provided on the opposite side of the display region **131** from the circuit **132**. Furthermore, as illustrated in FIG. **5**B, a circuit **153** may be provided on the opposite side of the display region **131** from the circuit **133**. FIGS. **5**A and **5**B each illustrate an example in which each scan line **135** is connected to the circuit **152** and the circuit **132**. However, the connection relation is not limited to this. For example, each scan line **135** may be connected to one of the circuit **132** and the circuit **152**. FIG. **5**B illustrates an example in which each signal line **136** is connected to the circuit **153** and the circuit **133**. However, the connection relation is not limited to this. For example, each signal line **136** may be connected to one of the circuit **133** and the circuit **153**. The circuits **132**, **133**, **152**, and **153** may have a function other than the function of driving the pixel **130**.

In some cases, the circuits **132**, **133**, **152**, and **153** may be collectively called a driver circuit portion. The pixel **130** includes a pixel circuit **137** and a display element. The pixel circuit **137** is a circuit that drives the display element. A transistor included in the driver circuit portion and a transistor included in the pixel circuit **137** can be formed at the same time. Part or the entire driver circuit portion may be formed over another substrate and electrically connected to the display device **100**. For example, part or the entire driver circuit portion may be formed over a single crystal substrate and electrically connected to the display device **100**.

FIGS. **4**B and **4**C illustrate circuit configurations that can be used for the pixels **130** in the display device illustrated in FIG. **4**A.

[Example of Pixel Circuit for Light-Emitting Display Device]

The pixel circuit **137** illustrated in FIG. **4**B includes a transistor **431**, a capacitor **233**, the transistor **232**, and a transistor **434**. The pixel circuit **137** is electrically connected to the light-emitting element **125** that can function as a display element.

One of a source electrode and a drain electrode of the transistor **431** is electrically connected to the signal line **136** in the n-th column to which a data signal is supplied (hereinafter referred to as a signal line DL_n). A gate electrode of the transistor **431** is electrically connected to the scan line **135** in the m-th row to which a gate signal is supplied (hereinafter referred to as a scan line GL_m).

The transistor **431** has a function of controlling whether to write a data signal to a node **435**.

One of a pair of electrodes of the capacitor **233** is electrically connected to the node **435**, and the other is electrically connected to a node **437**. The other of the source electrode and the drain electrode of the transistor **431** is electrically connected to the node **435**.

The capacitor **233** functions as a storage capacitor for storing data written to the node **435**.

One of a source electrode and a drain electrode of the transistor **232** is electrically connected to a potential supply line VL_a, and the other is electrically connected to the node **437**. A gate electrode of the transistor **232** is electrically connected to the node **435**.

One of a source electrode and a drain electrode of the transistor **434** is electrically connected to a potential supply line V**0**, and the other of the source electrode and the drain electrode of the transistor **434** is electrically connected to the node **437**. A gate electrode of the transistor **434** is electrically connected to the scan line GL_m.

One of an anode and a cathode of the light-emitting element **125** is electrically connected to a potential supply line VL_b, and the other is electrically connected to the node **437**.

As the light-emitting element **125**, an organic electroluminescent element (also referred to as an organic EL element) or the like can be used, for example. Note that the light-emitting element **125** is not limited to organic EL elements; an inorganic EL element including an inorganic material can be used, for example.

As a power supply potential, a potential on the relatively high potential side or a potential on the relatively low potential side can be used, for example. A power supply potential on the high potential side is referred to as a high power supply potential (also referred to as VDD), and a power supply potential on the low potential side is referred to as a low power supply potential (also referred to as VSS). A ground potential can be used as the high power supply potential or the low power supply potential. For example, in the case where a ground potential is used as the high power supply potential, the low power supply potential is a potential lower than the ground potential, and in the case where a ground potential is used as the low power supply potential, the high power supply potential is a potential higher than the ground potential.

For example, a potential supply line VL_a has a function of supplying VDD. A potential supply line VL_b and a potential supply line V**0** each have a function of supplying VSS.

Here, an operation example of a display device including the pixel circuit **137** illustrated in FIG. **4**B is described. First, the pixel circuits **137** are selected by the circuit **132** row by row, so that the transistor **431** is turned on and a data signal (potential) is written to the node **435**. At the same time, the transistors **434** are turned on and the potential of the node **437** is set to VSS.

Then, the transistor **431** is turned off and the data signal written to the node **435** is held. At the same time, the transistor **434** is turned off. The amount of current flowing between a source and a drain of the transistor **232** is determined in accordance with the data signal written to the node **435**. Therefore, the light-emitting element **125** emits light with a luminance corresponding to the amount of flowing current. This operation is sequentially performed row by row; thus, an image can be displayed.

[Example of Pixel Circuit for Liquid Crystal Display Device]

The pixel circuit **137** illustrated in FIG. **4**C includes the transistor **431** and the capacitor **233**. The pixel circuit **137** is electrically connected to a liquid crystal element **432** that can function as a display element.

The potential of one of a pair of electrodes of the liquid crystal element **432** is set according to the specifications of the pixel circuits **137** as appropriate. For example, a common potential may be applied to one of the pair of electrodes of the liquid crystal element **432**. The alignment state of the liquid crystal element **432** depends on data written to a node **436**.

As examples of a mode of the display device including the liquid crystal element **432**, any of the following modes can be given: a TN mode, an STN mode, a VA mode, an axially symmetric aligned micro-cell (ASM) mode, an optically compensated birefringence (OCB) mode, a ferroelectric liquid crystal (FLC) mode, an antiferroelectric liquid crystal (AFLC) mode, an MVA mode, a patterned vertical alignment (PVA) mode, an IPS mode, an FFS mode, a transverse bend alignment (TBA) mode, and the like. Other examples of the mode of the display device include an electrically controlled birefringence (ECB) mode, a polymer dispersed liquid crystal (PDLC) mode, a polymer network liquid crystal (PNLC) mode, and a guest-host mode. Note that the present invention is not limited to these examples, and various modes can be employed.

The liquid crystal element **432** may be formed using a liquid crystal composition including liquid crystal exhibiting a blue phase and a chiral material. The liquid crystal exhibiting a blue phase has a short response time of 1 msec or less. Since the liquid crystal exhibiting a blue phase is optically isotropic, alignment treatment is not necessary and viewing angle dependence is small.

In the pixel circuit **137** in the m-th row and the n-th column, one of a source electrode and a drain electrode of the transistor **431** is electrically connected to a signal line DL_n, and the other is electrically connected to the node **436**. A gate electrode of the transistor **431** is electrically connected to a scan line GL_m. The transistor **431** has a function of controlling whether to write a data signal to the node **436**.

One of a pair of electrodes of the capacitor **233** is electrically connected to a wiring to which a particular potential is supplied (hereinafter referred to as a capacitor line CL), and the other is electrically connected to the node **436**. The other of the pair of electrodes of the liquid crystal element **432** is electrically connected to the node **436**. The potential of the capacitor line CL is set in accordance with the specifications of the pixel circuit **137** as appropriate. The capacitor **233** functions as a storage capacitor for storing data written to the node **436**.

Here, an operation example of a display device including the pixel circuit **137** illustrated in FIG. **4**C is described. First, the pixel circuits **137** are selected by the circuit **132** row by row, so that the transistor **431** is turned on and a data signal is written to the node **436**.

Next, the transistor **431** is turned off and the data signal written to the node **436** is held. The amount of light transmitting through the liquid crystal element **432** is determined in accordance with the data signal written to the node **436**. This operation is sequentially performed row by row; thus, an image can be displayed on the display region **131**.

[Display Element]

The display device of one embodiment of the present invention can employ various modes and can include various display elements. For example, the display device can include at least one of an electroluminescence (EL) element (e.g., an EL element including organic and inorganic materials, an organic EL element, or an inorganic EL element), an LED (e.g., a white LED, a red LED, a green LED, or a blue LED), a transistor (a transistor that emits light depending on current), an electron emitter, a liquid crystal element, electronic ink, an electrophoretic element, a grating light valve (GLV), a plasma display panel (PDP), a display element using micro electro mechanical system (MEMS), a digital micromirror device (DMD), a digital micro shutter (DMS), MIRASOL (registered trademark), an interferometric modulator display (IMOD) element, a MEMS shutter display element, an optical-interference-type MEMS display element, an electrowetting element, a piezoelectric ceramic display, and a display element using a carbon nanotube. Other than the above, display media whose contrast, luminance, reflectivity, transmittance, or the like is changed by electrical or magnetic effect may be included. Alternatively, quantum dots may be used as the display element. Examples of display devices having EL elements include an EL display. Examples of a display device including an electron emitter include a field emission display (FED) and an SED-type flat panel display (SED: surface-conduction electron-emitter display). Examples of display devices including quantum dots include a quantum dot display. Examples of display devices including liquid crystal elements include a liquid crystal display (e.g., a transmissive liquid crystal display, a transflective liquid crystal display, a reflective liquid crystal display, a direct-view liquid crystal display, or a projection liquid crystal display). Examples of a display device including electronic ink, electronic liquid powder (registered trademark), or electrophoretic elements include electronic paper. In the case of a transflective liquid crystal display or a reflective liquid crystal display, some or all of pixel electrodes function as reflective electrodes. For example, some or all of pixel electrodes are formed to contain aluminum, silver, or the like. In such a case, a memory circuit such as an SRAM can be provided under the reflective electrodes, leading to lower power consumption.

Note that in the case of using an LED, graphene or graphite may be provided under an electrode or a nitride semiconductor of the LED. Graphene or graphite may be a multilayer film in which a plurality of layers are stacked. As described above, provision of graphene or graphite enables easy formation of a nitride semiconductor film thereover, such as an n-type GaN semiconductor layer including crystals.

Furthermore, a p-type GaN semiconductor layer including crystals or the like can be provided thereover, and thus the LED can be formed. Note that an AlN layer may be provided between the n-type GaN semiconductor layer including crystals and graphene or graphite. The GaN semiconductor layers included in the LED may be formed by metal organic chemical vapor deposition (MOCVD). Note that when the graphene is provided, the GaN semiconductor layers included in the LED can also be formed by a sputtering method.

<Example of Pixel Configuration for Achieving Color Display>

Here, examples of a pixel configuration for achieving color display are described with reference to FIGS. **6**A and **6**B. FIGS. **6**A and **6**B and FIGS. **7**A and **7**B are enlarged plan views of a region **170** in the display region **131** of FIG. **1**. As illustrated in FIG. **6**A, for example, each pixel **130** may function as a subpixel and three pixels **130** may be collectively used as one pixel **140**. The use of a red, a green, and a blue coloring layers as the coloring layers **266** for the three pixels **130** enables full-color display. In FIG. **6**A, the pixel **130** emitting red light, the pixel **130** emitting green light, and the pixel **130** emitting blue light are illustrated as a pixel **130**R, a pixel **130**G, and a pixel **130**B, respectively. The colors of the coloring layers **266** may be a color other than red, green, and blue; for example, the colors of the coloring layer **266** may be yellow, cyan, magenta, or the like.

As illustrated in FIG. **6**B, each pixel **130** may function as a subpixel and four pixels **130** may be collectively used as one pixel **140**. For example, the coloring layers **266** corresponding to the four pixels **130** may be red, green, blue, and yellow. In FIG. **6**B, the pixel **130** emitting red light, the pixel **130** emitting green light, the pixel **130** emitting blue light, and the pixel **130** emitting yellow light are illustrated as a pixel **130**R, a pixel **130**G, a pixel **130**B, and a pixel **130**Y, respectively. By increasing the number of subpixels (pixels **130**) included in one pixel **140**, the color reproduction range can be widened.

Alternatively, the coloring layers **266** corresponding to the four pixels **130** may be red, green, blue, and white (see FIG. **6**B). With the pixel **130** emitting white light (pixel **130**W), the luminance of the display region can be increased. Note that in the case where the pixel **130**W emitting white light is provided, it is not necessary to provide the coloring layer **266** for the pixel **130**W. Without the coloring layer **266** for the pixel **130**W, there is no luminance reduction at the time of transmitting light through the coloring layer **266**; thus, the luminance of the display region can be increased. Moreover, power consumption of the display device can be reduced. On the other hand, color temperature of white light can be controlled with the coloring layer **266** for the pixel **130**W. Thus, the display quality of the display device can be improved. Depending on the intended use of the display device, each pixel **130** may function as a subpixel and two pixels **130** may be collectively used as one pixel **140**.

In the case where the four pixels **130** are collectively used as one pixel **140**, the four pixels **130** may be arranged in a matrix, as in FIG. **7**B. In addition, in the case where the four pixels **130** are collectively used as one pixel **140**, a pixel that emits light of cyan, magenta, or the like may be used instead of the pixel **130**Y or the pixel **130**W. A plurality of pixels **130** that emit light of the same color may be provided in the pixel **140**.

Note that the occupation areas or shapes of the pixels **130** included in the pixel **140** may be the same or different. In addition, arrangement is not limited to stripe arrangement or matrix arrangement. For example, delta arrangement, Bayer arrangement, pentile arrangement, or the like can be used. FIG. **7**A illustrates an example of pentile arrangement.

In Embodiment 1, one embodiment of the present invention has been described. Other embodiments of the present invention are described in Embodiments 2 to 8. Note that one embodiment of the present invention is not limited to the description in Embodiments 1 to 8. An example where the layer **147** covers the whole display device is described; however, one embodiment of the present invention is not limited to this example. Depending on circumstances or conditions, a display device of one embodiment of the present invention may have a region which is not covered with the layer **147**. Alternatively, depending on circumstances or conditions, a display device of one embodiment of the present invention is not necessarily covered with the layer **147**.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 2

In this embodiment, an example of a method for manufacturing the display device **100** is described with reference to FIGS. **8**A to **8**D, FIGS. **9**A to **9**D, FIGS. **10**A to **10**D, FIGS. **11**A and **11**B, FIGS. **12**A and **12**B, FIGS. **13**A and **13**B, FIGS. **14**A and **14**B, FIGS. **15**A and **15**B, FIGS. **16**A to **16**C, FIG. **17**, FIGS. **18A1** to **18**B3, FIG. **19**, FIGS. **20**A and **20**B, FIGS. **21**A and **21**B, FIGS. **22**A and **22**B, FIG. **23**, and FIG. **24**. Note that FIGS. **8**A to **8**D, FIGS. **9**A to **9**D, FIGS. **11**A and **11**B, FIGS. **12**A and **12**B, FIGS. **13**A and **13**B, FIGS. **14**A and **14**B, FIGS. **20**A and **20**B, FIGS. **21**A and **21**B, FIGS. **22**A and **22**B, and FIG. **23** correspond to the cross section taken along the dashed-dotted line A**3**-A**4** in FIG. **15**A.

<Example of Method for Manufacturing Display Device>

[Formation of Separation Layer]

First, a separation layer **113** is formed over a substrate **101** (see FIG. **8**A). As the substrate **101**, a glass substrate, a quartz substrate, a sapphire substrate, a ceramic substrate, a metal substrate, or the like can be used. Alternatively, a plastic substrate having heat resistance to the processing temperature in this embodiment may be used.

As the glass substrate, for example, a glass material such as aluminosilicate glass, aluminoborosilicate glass, or barium borosilicate glass is used. Note that when the glass substrate contains a large amount of barium oxide (BaO), the glass substrate can be heat-resistant and more practical. Alternatively, crystallized glass or the like can be used.

The separation layer **113** can be formed using an element selected from tungsten, molybdenum, titanium, tantalum, niobium, nickel, cobalt, zirconium, ruthenium, rhodium, palladium, osmium, iridium, and silicon; an alloy material containing any of the elements; or a compound material containing any of the elements. The separation layer **113** can also be formed to have a single-layer structure or a stacked-layer structure using any of the materials. Note that the crystalline structure of the separation layer **113** may be amorphous, microcrystalline, or polycrystalline. The separation layer **113** can also be formed using a metal oxide such as aluminum oxide, gallium oxide, zinc oxide, titanium dioxide, indium oxide, indium tin oxide, indium zinc oxide, or InGaZnO (IGZO).

The separation layer **113** can be formed by a sputtering method, a CVD method, a coating method, a printing method, or the like. Note that the coating method includes a spin coating method, a droplet discharge method, and a dispensing method.

In the case where the separation layer **113** has a single-layer structure, a material containing at least one of tungsten and molybdenum is preferably used. Alternatively, in the case where the separation layer **113** has a single-layer structure, an oxide or oxynitride of tungsten, an oxide or oxynitride of molybdenum, or an oxide or oxynitride of a material containing tungsten and molybdenum is preferably used.

In the case where the separation layer **113** has a stacked-layer structure including, for example, a layer containing tungsten and a layer containing an oxide of tungsten, the layer containing an oxide of tungsten may be formed as follows: the layer containing tungsten is formed first and then an oxide insulating layer is formed in contact therewith, so that the layer containing an oxide of tungsten is formed at the interface between the layer containing tungsten and the oxide insulating layer. Alternatively, the layer containing an oxide of tungsten may be formed by performing thermal oxidation treatment, oxygen plasma treatment, treatment with a highly oxidizing solution such as ozone water, or the like on the surface of the layer containing tungsten.

In this embodiment, a glass substrate is used as the substrate **101**. As the separation layer **113**, a tungsten layer is formed over the substrate **101** by a sputtering method.

[Formation of Insulating Layer]

Next, the insulating layer **205** is formed as a base layer over the separation layer **113** (see FIG. **8**A). The insulating layer **205** is preferably formed as a single layer or a multilayer using any of silicon oxide, silicon nitride, silicon oxynitride, silicon nitride oxide, aluminum oxide, aluminum oxynitride, and aluminum nitride oxide. The insulating layer **205** may have, for example, a two-layer structure of silicon oxide and silicon nitride or a five-layer structure in which materials selected from the above are combined. The insulating layer **205** can be formed by a sputtering method, a CVD method, a thermal oxidation method, a coating method, a printing method, or the like.

The thickness of the insulating layer **205** is greater than or equal to 30 nm and less than or equal to 500 nm, preferably greater than or equal to 50 nm and less than or equal to 400 nm.

The insulating layer **205** can prevent or reduce diffusion of impurity elements from the substrate **101**, the separation layer **113**, or the like. Even after the substrate **101** is replaced with the substrate **111**, the insulating layer **205** can prevent or reduce diffusion of impurity elements into the light-emitting element **125** from the substrate **111**, the bonding layer **112**, or the like. In this embodiment, the insulating layer **205** is formed by stacking a 200-nm-thick silicon oxynitride film and a 50-nm-thick silicon nitride oxide film by a plasma CVD method.

[Formation of Gate Electrode]

Next, the gate electrode **206** is formed over the insulating layer **205** (see FIG. **8**A). The gate electrode **206** can be formed using a metal element selected from aluminum, chromium, copper, tantalum, titanium, molybdenum, and tungsten; an alloy containing any of these metal elements as a component; an alloy containing any of these metal elements in combination; or the like. Further, one or more metal elements selected from manganese and zirconium may be used. The gate electrode **206** may have a single-layer structure or a stacked structure of two or more layers. For example, a single-layer structure of an aluminum film containing silicon, a two-layer structure in which an aluminum film is stacked over a titanium film, a two-layer structure in which a titanium film is stacked over a titanium nitride film, a two-layer structure in which a tungsten film is stacked over a titanium nitride film, a two-layer structure in which a tungsten film is stacked over a tantalum nitride film or a tungsten nitride film, a two-layer structure in which a copper film is stacked over a titanium film, a three-layer structure in which a titanium film, an aluminum film, and a titanium film are stacked in this order, and the like can be given. Alternatively, a film, an alloy film, or a nitride film which contains aluminum and one or more elements selected from titanium, tantalum, tungsten, molybdenum, chromium, neodymium, and scandium may be used.

The gate electrode **206** can be formed using a light-transmitting conductive material such as indium tin oxide, indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium zinc oxide, or indium tin oxide to which silicon oxide is added. It is also possible to have a stacked-layer structure formed using the above light-transmitting conductive material and the above metal element.

First, a conductive film to be the gate electrode **206** is stacked over the insulating layer **205** by a sputtering method, a CVD method, an evaporation method, or the like, and a resist mask is formed over the conductive film by a photolithography process. Next, part of the conductive film to be the gate electrode **206** is etched with the use of the resist mask to form the gate electrode **206**. At the same time, a wiring and another electrode can be formed.

The conductive film may be etched by a dry etching method, a wet etching method, or both a dry etching method and a wet etching method. Note that in the case where the conductive film is etched by a dry etching method, ashing treatment may be performed before the resist mask is removed, whereby the resist mask can be easily removed using a stripper.

Note that the gate electrode **206** may be formed by an electrolytic plating method, a printing method, an inkjet method, or the like instead of the above formation method.

The thickness of the gate electrode **206** is greater than or equal to 5 nm and less than or equal to 500 nm, preferably greater than or equal to 10 nm and less than or equal to 300 nm, more preferably greater than or equal to 10 nm and less than or equal to 200 nm.

The gate electrode **206** may be formed using a light-blocking conductive material, whereby external light can be prevented from reaching the semiconductor layer **208** from the gate electrode **206** side. As a result, a variation in electrical characteristics of the transistor due to light irradiation can be suppressed.

[Formation of Gate Insulating Layer]

Next, the gate insulating layer **207** is formed (see FIG. **8**A). The gate insulating layer **207** can be formed to have a single-layer structure or a stacked-layer structure using, for example, any of silicon oxide, silicon oxynitride, silicon nitride oxide, silicon nitride, aluminum oxide, a mixture of aluminum oxide and silicon oxide, hafnium oxide, gallium oxide, Ga—Zn-based metal oxide, and the like.

The gate insulating layer **207** may be formed using a high-k material such as hafnium silicate ($HfSiO_x$), hafnium silicate to which nitrogen is added ($HfSi_xO_yN_z$), hafnium aluminate to which nitrogen is added ($HfAl_xO_yN_z$), hafnium oxide, or yttrium oxide, so that gate leakage current of the transistor can be reduced. For example, a stacked layer of silicon oxynitride and hafnium oxide may be used.

The thickness of the gate insulating layer **207** is preferably greater than or equal to 5 nm and less than or equal to 400 nm, further preferably greater than or equal to 10 nm and less than or equal to 300 nm, still further preferably greater than or equal to 50 nm and less than or equal to 250 nm.

The gate insulating layer **207** can be formed by a sputtering method, a CVD method, an evaporation method, or the like.

In the case where a silicon oxide film, a silicon oxynitride film, or a silicon nitride oxide film is formed as the gate insulating layer **207**, a deposition gas containing silicon and an oxidizing gas are preferably used as a source gas. Typical examples of the deposition gas containing silicon include silane, disilane, trisilane, and silane fluoride. As the oxidizing gas, oxygen, ozone, dinitrogen monoxide, nitrogen dioxide, and the like can be given as examples.

The gate insulating layer **207** can have a stacked-layer structure in which a nitride insulating layer and an oxide insulating layer are stacked in this order from the gate electrode **206** side. When the nitride insulating layer is provided on the gate electrode **206** side, hydrogen, nitrogen, an alkali metal, an alkaline earth metal, or the like can be prevented from moving from the gate electrode **206** side to the semiconductor layer **208**. Note that nitrogen, an alkali metal, an alkaline earth metal, or the like generally serves as an impurity element of a semiconductor. In addition, hydrogen serves as an impurity element of an oxide semiconductor. Thus, an “impurity” in this specification and the like includes hydrogen, nitrogen, an alkali metal, an alkaline earth metal, or the like.

In the case where an oxide semiconductor is used for the semiconductor layer **208**, the density of defect states at the interface between the gate insulating layer **207** and the semiconductor layer **208** can be reduced by providing the oxide insulating layer on the semiconductor layer **208** side. Consequently, a transistor whose electrical characteristics are hardly degraded can be obtained. Note that in the case where an oxide semiconductor is used for the semiconductor layer **208**, an oxide insulating layer containing oxygen in a proportion higher than that in the stoichiometric composition is preferably formed as the oxide insulating layer. This is because the density of defect states at the interface between the gate insulating layer **207** and the semiconductor layer **208** can be further reduced.

In the case where the gate insulating layer **207** is a stacked layer of a nitride insulating layer and an oxide insulating layer as described above, it is preferable that the nitride insulating layer be thicker than the oxide insulating layer.

The nitride insulating layer has a dielectric constant higher than that of the oxide insulating layer; therefore, an electric field generated from the gate electrode **206** can be efficiently transmitted to the semiconductor layer **208** even when the gate insulating layer **207** has a large thickness. When the gate insulating layer **207** has a large total thickness, the withstand voltage of the gate insulating layer **207** can be increased. Accordingly, the reliability of the semiconductor device can be improved.

The gate insulating layer **207** can have a stacked-layer structure in which a first nitride insulating layer with few defects, a second nitride insulating layer with a high blocking property against hydrogen, and an oxide insulating layer are stacked in that order from the gate electrode **206** side. When the first nitride insulating layer with few defects is used in the gate insulating layer **207**, the withstand voltage of the gate insulating layer **207** can be improved. Particularly when an oxide semiconductor is used for the semiconductor layer **208**, the use of the second nitride insulating layer with a high blocking property against hydrogen in the gate insulating layer **207** makes it possible to prevent hydrogen contained in the gate electrode **206** and the first nitride insulating layer from moving to the semiconductor layer **208**.

An example of a method for forming the first and second nitride insulating layers is described below. First, a silicon nitride film with few defects is formed as the first nitride insulating layer by a plasma CVD method in which a mixed gas of silane, nitrogen, and ammonia is used as a source gas. Next, a silicon nitride film in which the hydrogen concentration is low and hydrogen can be blocked is formed as the second nitride insulating layer by switching the source gas to a mixed gas of silane and nitrogen. By such a formation method, the gate insulating layer **207** in which nitride insulating layers with few defects and a blocking property against hydrogen are stacked can be formed.

The gate insulating layer **207** can have a structure in which a third nitride insulating layer with a high blocking property against an impurity, the first nitride insulating layer with few defects, the second nitride insulating layer with a high blocking property against hydrogen, and the oxide insulating layer are stacked in that order from the gate electrode **206** side. When the third nitride insulating layer with a high blocking property against an impurity is provided in the gate insulating layer **207**, hydrogen, nitrogen, alkali metal, alkaline earth metal, or the like, can be prevented from moving from the gate electrode **206** to the semiconductor layer **208**.

An example of a method for forming the first to third nitride insulating layers is described below. First, a silicon nitride film with a high blocking property against an impurity is formed as the third nitride insulating layer by a plasma CVD method in which a mixed gas of silane, nitrogen, and ammonia is used as a source gas. Next, a silicon nitride film with few defects is formed as the first nitride insulating layer by increasing the flow rate of ammonia. Then, a silicon nitride film in which the hydrogen concentration is low and hydrogen can be blocked is formed as the second nitride insulating layer by switching the source gas to a mixed gas of silane and nitrogen. By such a formation method, the gate insulating layer **207** in which nitride insulating layers with few defects and a blocking property against an impurity are stacked can be formed.

Moreover, in the case of forming a gallium oxide film as the gate insulating layer **207**, an MOCVD method can be employed.

Note that the threshold voltage of a transistor can be changed by stacking the semiconductor layer **208** in which a channel of the transistor is formed and an insulating layer containing hafnium oxide with an oxide insulating layer provided therebetween and injecting electrons into the insulating layer containing hafnium oxide.

[Formation of Semiconductor Layer]

The semiconductor layer **208** can be formed using an amorphous semiconductor, a microcrystalline semiconductor, a polycrystalline semiconductor, or the like. For example, amorphous silicon or microcrystalline germanium can be used. Alternatively, a compound semiconductor such as silicon carbide, gallium arsenide, an oxide semiconductor, or a nitride semiconductor, an organic semiconductor, or the like can be used.

First, a semiconductor film for forming the semiconductor layer **208** is formed by a CVD method such as a plasma CVD method, an LPCVD method, a metal CVD method, or an MOCVD method, an ALD method, a sputtering method, an evaporation method, or the like. When the semiconductor film is formed by an MOCVD method, damage to a surface where the semiconductor layer is formed can be reduced.

Next, a resist mask is formed over the semiconductor film, and part of the semiconductor film is selectively etched using the resist mask to form the semiconductor layer **208**. The resist mask can be formed by a photolithography method, a printing method, an inkjet method, or the like as appropriate. Formation of the resist mask by an inkjet method needs no photomask; thus, fabrication cost can be reduced.

Note that the etching of the semiconductor film may be performed by either one or both of a dry etching method and a wet etching method. After the etching of the semiconductor film, the resist mask is removed (see FIG. **8**B).

[Formation of Source Electrode, Drain Electrode, and the Like]

Next, the source electrode **209***a*, the drain electrode **209***b*, the wiring **219**, and the terminal electrode **216** are formed (see FIG. **8**C). First, a conductive film, which forms the source electrode **209***a*, the drain electrode **209***b*, the wiring **219**, and the terminal electrode **216**, is formed over the gate insulating layer **207** and the semiconductor layer **208**.

The conductive film can have a single-layer structure or a stacked-layer structure containing any of metals such as aluminum, titanium, chromium, nickel, copper, yttrium, zirconium, molybdenum, silver, tantalum, and tungsten or an alloy containing any of these metals as its main component. For example, the following structures can be given: a single-layer structure of an aluminum film containing silicon, a two-layer structure in which an aluminum film is stacked over a titanium film, a two-layer structure in which an aluminum film is stacked over a tungsten film, a two-layer structure in which a copper film is stacked over a copper-magnesium-aluminum alloy film, a two-layer structure in which a copper film is stacked over a titanium film, a two-layer structure in which a copper film is stacked over a tungsten film, a three-layer structure in which a titanium film or a titanium nitride film, an aluminum film or a copper film, and a titanium film or a titanium nitride film are stacked in this order, a three-layer structure in which a molybdenum film or a molybdenum nitride film, an aluminum film or a copper film, and a molybdenum film or a molybdenum nitride film are stacked in this order, and a three-layer structure in which a tungsten film, a copper film, and a tungsten film are stacked in this order.

Note that a conductive material containing oxygen such as indium tin oxide, zinc oxide, indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium zinc oxide, or indium tin oxide to which silicon oxide is added, or a conductive material containing nitrogen such as titanium nitride or tantalum nitride may be used. It is also possible to use a stacked-layer structure formed using a material containing the above metal element and conductive material containing oxygen. It is also possible to use a stacked-layer structure formed using a material containing the above metal element and a conductive material containing nitrogen. It is also possible to use a stacked-layer structure formed using a material containing the above metal element, a conductive material containing oxygen, and a conductive material containing nitrogen.

The thickness of the conductive film is greater than or equal to 5 nm and less than or equal to 500 nm, preferably greater than or equal to 10 nm and less than or equal to 300 nm, more preferably greater than or equal to 10 nm and less than or equal to 200 nm. In this embodiment, a 300-nm-thick tungsten film is formed as the conductive film.

Then, part of the conductive film is selectively etched using a resist mask to form the source electrode **209***a*, the drain electrode **209***b*, the wiring **219**, and the terminal electrode **216** (including other electrodes and wirings formed using the same layer). The resist mask can be formed by a photolithography method, a printing method, an inkjet method, or the like as appropriate. Formation of the resist mask by an inkjet method needs no photomask; thus, fabrication cost can be reduced.

The conductive film may be etched by a dry etching method, a wet etching method, or both a dry etching method and a wet etching method. Note that an exposed portion of the semiconductor layer **208** is removed by the etching step in some cases. After the etching of the conductive film, the resist mask is removed.

With the source electrode **209***a* and the drain electrode **209***b*, the transistor **232** and the transistor **252** are completed.

[Formation of Insulating Layer]

Next, the insulating layer **210** is formed over the source electrode **209***a*, the drain electrode **209***b*, the wiring **219**, and the terminal electrode **216** (see FIG. **8**D). The insulating layer **210** can be formed using a material and a method similar to those of the insulating layer **205**.

In the case where an oxide semiconductor is used for the semiconductor layer **208**, an insulating layer containing oxygen is preferably used for at least part of the insulating layer **210** that is in contact with the semiconductor layer **208**. For example, in the case where the insulating layer **210** is a stack of a plurality of layers, at least a layer that is in contact with the semiconductor layer **208** is preferably formed using silicon oxide.

[Formation of Opening]

Next, part of the insulating layer **210** is selectively etched using a resist mask to form an opening **128** (see FIG. **8**D). At the same time, another opening that is not illustrated can also be formed. The resist mask can be formed by a photolithography method, a printing method, an inkjet method, or the like as appropriate. Formation of the resist mask by an inkjet method needs no photomask; thus, fabrication cost can be reduced.

The insulating layer **210** may be etched by a dry etching method, a wet etching method, or both a dry etching method and a wet etching method.

The drain electrode **209***b* and the terminal electrode **216** are partly exposed by the formation of the opening **128**. The resist mask is removed after the formation of the opening **128**.

[Formation of Planarization Film]

Next, the insulating layer **211** is formed over the insulating layer **210** (see FIG. **9**A). The insulating layer **211** can be formed using a material and a method similar to those of the insulating layer **205**.

Planarization treatment may be performed on the insulating layer **211** to reduce unevenness of a surface on which the light-emitting element **125** is formed. The planarization treatment may be, but not particularly limited to, polishing treatment (e.g., chemical mechanical polishing (CMP)) or dry etching treatment.

Forming the insulating layer **211** using an insulating material with a planarization function can make polishing treatment unnecessary. As the insulating material with a planarization function, for example, an organic material such as a polyimide resin or an acrylic resin can be used. Besides such organic materials, a low-dielectric constant material (a low-k material) or the like can be used. Note that the insulating layer **211** may be formed by stacking a plurality of insulating layers formed of any of these materials.

Part of the insulating layer **211** that overlaps with the opening **128** is removed to form an opening **129**. At the same time, another opening that is not illustrated is also formed. In addition, the insulating layer **211** in a region to which the external electrode **124** is connected later is removed. Note that the opening **129** or the like can be formed in such a manner that a resist mask is formed by a photolithography process over the insulating layer **211** and a region of the insulating layer **211** that is not covered with the resist mask is etched. A surface of the drain electrode **209***b* is exposed by the formation of the opening **129**.

When the insulating layer **211** is formed using a photosensitive material, the opening **129** can be formed without the resist mask. In this embodiment, a photosensitive polyimide resin is used to form the insulating layer **211** and the opening **129**.

[Formation of Anode]

Next, the electrode **115** is formed over the insulating layer **211** (see FIG. **9**B). The electrode **115** is preferably formed using a conductive material that efficiently reflects light emitted from the EL layer **117** formed later. Note that the electrode **115** may have a stacked-layer structure of a plurality of layers without limitation to a single-layer structure. For example, in the case where the electrode **115** is used as an anode, a layer in contact with the EL layer **117** may be a light-transmitting layer, such as an indium tin oxide layer, having a work function higher than that of the EL layer **117**, and a layer having high reflectance (e.g., aluminum, an alloy containing aluminum, or silver) may be provided in contact with the layer.

The electrode **115** can be formed in such a manner that a conductive film to be the electrode **115** is formed over the insulating layer **211**, a resist mask is formed over the conductive film, and a region of the conductive film that is not covered with the resist mask is etched. The conductive film can be etched by a dry etching method, a wet etching method, or both a dry etching method and a wet etching method. The resist mask can be formed by a photolithography method, a printing method, an inkjet method, or the like as appropriate. Formation of the resist mask by an inkjet method needs no photomask; thus, fabrication cost can be reduced. The resist mask is removed after the formation of the electrode **115**.

[Formation of Partition]

Next, the partition **114** is formed (see FIG. **9**C). The partition **114** is provided in order to prevent an unintended electrical short-circuit between light-emitting elements **125** in adjacent pixels and unintended light emission from the light-emitting element **125**. In the case of using a metal mask for formation of the EL layer **117** described later, the partition **114** has a function of preventing the contact of the metal mask with the electrode **115**. The partition **114** can be formed of an organic resin material such as an epoxy resin, an acrylic resin, or an imide resin or an inorganic material such as silicon oxide. The partition **114** is preferably formed so that its sidewall has a tapered shape or a tilted surface with a continuous curvature. The sidewall of the partition **114** having the above-described shape enables favorable coverage with the EL layer **117** and the electrode **118** formed later.

[Formation of EL Layer]

A structure of the EL layer **117** is described in Embodiment 7.

[Formation of Cathode]

The electrode **118** is used as a cathode in this embodiment, and thus is preferably formed using a material that has a low work function and can inject electrons into the EL layer **117** described later. As well as a single-layer of a metal having a low work function, a stack in which a metal material such as aluminum, a conductive oxide material such as indium tin oxide, or a semiconductor material is formed over a several-nanometer-thick buffer layer formed of an alkali metal or an alkaline earth metal having a low work function may be used as the electrode **118**.

In the case where light emitted from the EL layer **117** is extracted through the electrode **118**, the electrode **118** preferably has a property of transmitting visible light. The light-emitting element **125** includes the electrode **115**, the EL layer **117**, and the electrode **118** (see FIG. **9**D).

In this embodiment, the substrate **101** including the transistor **232** and the light-emitting element **125** is referred to as an element substrate **171**.

[Formation of Counter Substrate]

The separation layer **143** and the insulating layer **145** are formed over the element formation substrate **141** (see FIG. **10**A). The element formation substrate **141** can be formed using a material similar to that of the substrate **101**. The separation layer **143** can be formed using a material and a method similar to those of the separation layer **113**. The insulating layer **145** can be formed using a material and a method similar to those of the insulating layer **205**.

Next, the light-blocking layer **264** is formed over the insulating layer **145** (see FIG. **10**B). After that, the coloring layer **266** is formed (see FIG. **10**C).

The light-blocking layer **264** and the coloring layer **266** each are formed in a desired position with any of various materials by a printing method, an inkjet method, a photolithography method, or the like.

Next, the overcoat layer **268** is formed over the light-blocking layer **264** and the coloring layer **266** (see FIG. **10**D).

For the overcoat layer **268**, an organic insulating layer of an acrylic resin, an epoxy resin, polyimide, or the like can be used. With the overcoat layer **268**, for example, an impurity or the like contained in the coloring layer **266** can be prevented from diffusing into the light-emitting element **125** side. Note that the overcoat layer **268** is not necessarily formed.

A light-transmitting conductive film may be formed as the overcoat layer **268**. The light-transmitting conductive film is formed as the overcoat layer **268**, so that the light **235** emitted from the light-emitting element **125** can be transmitted through the overcoat layer **268**, while ionized impurities can be prevented from passing through the overcoat layer **268**.

The light-transmitting conductive film can be formed using, for example, indium oxide, indium tin oxide (ITO), indium zinc oxide, zinc oxide, or zinc oxide to which gallium is added. Graphene or a metal film that is thin enough to have a light-transmitting property can also be used.

Through the above-described steps, the components such as the coloring layer **266** can be formed over the element formation substrate **141**. In this embodiment, the element formation substrate **141** including the coloring layer **266** and the like is referred to as a counter substrate **181**.

[Attachment of Element Substrate to Counter Substrate]

Next, the element substrate **171** is attached to the counter substrate **181** with bonding layer **120** positioned therebetween such that the light-emitting element **125** included in the element substrate **171** faces the coloring layer **266** included in the counter substrate **181** (see FIG. **11**A).

A light curable adhesive, a reactive curable adhesive, a thermosetting adhesive, or an anaerobic adhesive can be used as the bonding layer **120**. For example, an epoxy resin, an acrylic resin, or an imide resin can be used. In a top-emission structure, a drying agent (e.g., zeolite) having a size less than or equal to the wavelength of light or a filler (e.g., titanium oxide or zirconium) with a high refractive index is preferably mixed into the bonding layer **120**, in which case the efficiency of extracting light emitted from the EL layer **117** can be improved.

[Separation of Substrate **101** from Insulating Layer]

Next, the substrate **101** and the separation layer **113** are separated from the insulating layer **205** (see FIG. **11**B). As a separation method, mechanical force (a separation process with a human hand or a gripper, a separation process by rotation of a roller, ultrasonic waves, or the like) may be used. For example, a cut is made in the separation layer **113** with a sharp edged tool, by laser light irradiation, or the like and water is injected into the cut. Alternatively, the cut is sprayed with a mist of water. A portion between the separation layer **113** and the insulating layer **205** absorbs water through capillarity action, so that the substrate **101** with the separation layer **113** can be separated easily from the insulating layer **205**.

[Bonding of Substrate **111**]

Next, the substrate **111** is attached to the insulating layer **205** with the bonding layer **112** therebetween (see FIGS. **12**A and **12**B). The bonding layer **112** can be formed using a material similar to that of the bonding layer **120**. In this embodiment, a 20-μm-thick aramid (polyamide resin) with a Young's modulus of 10 GPa is used for the substrate **111**.

[Separation of Element Formation Substrate **141** from Insulating Layer]

Next, the element formation substrate **141** with the separation layer **143** is separated from the insulating layer **145** (see FIG. **13**A). The element formation substrate **141** can be separated in a manner similar to that of the above-described separation method of the substrate **101**.

[Bonding of Substrate **121**]

Next, the substrate **121** is attached to the insulating layer **145** with the bonding layer **142** therebetween (see FIG. **13**B). The bonding layer **142** can be formed using a material similar to that of the bonding layer **120**. The substrate **121** can be formed using a material similar to that of the substrate **111**.

[Formation of Opening]

Next, the substrate **121**, the bonding layer **142**, the insulating layer **145**, the coloring layer **266**, the overcoat layer **268**, and the bonding layer **120** in a region overlapping with the terminal electrode **216** and the opening **128** are removed to form the opening **122** (see FIG. **14**A). A surface of the terminal electrode **216** is partly exposed by the formation of the opening **122**.

[Formation of External Electrode]

Next, the anisotropic conductive connection layer **123** is formed in and over the opening **122**, and the external electrode **124** is formed over the anisotropic conductive connection layer **123** (see FIG. **14**B). The external electrode **124** is electrically connected to the terminal electrode **216** through the anisotropic conductive connection layer **123**. Power or a signal is supplied to the display device **100** through the external electrode **124** and the terminal electrode **216**. For example, a flexible printed circuit (FPC) or a tape carrier package (TCP) can be used as the external electrode **124**. The TCP is, for example, a tape automated bonding (TAB) tape mounted with a semiconductor chip on which an integrated circuit is formed. The semiconductor chip is electrically connected to the terminal electrode **216** through the TAB tape.

The anisotropic conductive connection layer **123** can be formed using any of various anisotropic conductive films (ACF), anisotropic conductive pastes (ACP), and the like.

The anisotropic conductive connection layer **123** is formed by curing a paste-form or sheet-form material that is obtained by mixing conductive particles to a thermosetting resin or a thermosetting, light curable resin. The anisotropic conductive connection layer **123** exhibits an anisotropic conductive property by light irradiation or thermocompression bonding. As the conductive particles used for the anisotropic conductive connection layer **123**, for example, particles of a spherical organic resin coated with a thin-film metal such as Au, Ni, or Co can be used.

Note that a metal wire can also be used as the external electrode **124**. Although the anisotropic conductive connection layer **123** may be used to connect the metal wire and the terminal electrode **216** to each other, the connection may be performed by a wire bonding method without using the anisotropic conductive connection layer **123**. Alternatively, the metal wire and the terminal electrode **216** may be connected to each other by a soldering method.

In the above-described manner, the display device **100** to which the external electrode **124** is connected can be fabricated. FIG. **15**A is a perspective view of the display device **100** to which the external electrode **124** is connected. Note that the substrate **121** may be formed to cover the display region **131**, the circuit **132**, and the circuit **133** and not to cover the other regions. An example of a display device having such a structure is illustrated in FIG. **15**B. A display device **200** illustrated in FIG. **15**B is different from the display device **100** in that the substrate **121** is not provided in a connection region of the external electrode **124**. Therefore, the external shapes of the substrate **111** and the substrate **121** included in the display device **200** are different.

[Formation of Layer **147**]

Next, the display device **100** is covered with the layer **147**. An example of a method for forming the layer **147** that covers the display device **100** is described with reference to FIGS. **16**A to **16**C. A structure body **191** illustrated in FIG. **16**A has a depressed portion **192**. A structure body **193** has a depressed portion **194**. The depressed portion **192** and the depressed portion **194** are preferably similar in shape. The surfaces of the depressed portion **192** and the depressed portion **194** preferably have high planarity by being subjected to mirror finishing or the like.

For example, metallic molds can be used as the structure bodies **191** and **193**. A material used for the structure bodies **191** and **193** is not limited to metal. For example, glass, ceramic, an organic resin, or wood may be used.

First, the structure body **191** and the structure body **193** are overlapped such that the depressed portion **192** and the depressed portion **194** face each other. Next, the display device **100** to which the external electrode **124** is connected is disposed in a space surrounded by the depressed portion **192** and the depressed portion **194** (see FIG. **16**B).

Next, the space surrounded by the depressed portion **192** and the depressed portion **194** is filled with a liquid filler **195**. As the filler **195**, it is preferable to use a high molecular material that exhibits a light transmitting property after being cured. As the filler **195**, a single-component-type material that does not need a curing agent or a two-component-type material that is cured by mixing a main agent and a curing agent can be used, for example. Alternatively, a material that is cured by heating, irradiation with light such as ultraviolet light can be used. The filler **195** may include a desiccant that inhibits permeation of moisture.

In this embodiment, a two-component-type material that becomes light-transmitting silicone rubber after being cured is used as the filler **195**.

The filler **195** is cured to have the shape of the depressed portion **192** and the depressed portion **194**, whereby the layer **147** can be formed. After the formation of the layer **147**, the structure body **191** and the structure body **193** are separated (see FIG. **17**). Note that it is preferable to apply a remover onto surfaces of the depressed portion **192** and the depressed portion **194** before the space is filled with the filler **195**, in which case the layer **147** can be separated easily from the structure body **191** and the structure body **193**.

FIG. **18**A1 is a perspective view of the display device **100** to which the external electrode **124** is connected and which is covered with the layer **147**. FIG. **18**A2 is a cross-sectional view taken along the dashed-dotted line H1-H2 in FIG. **18**A1. With the layer **147** that covers the display device **100**, the display device is less likely to be broken even when being bent and extended repeatedly. The layer **147** that covers the display device **100** is seamless. By covering the edges of the substrate **111** and the substrate **121** with the layer **147**, entry of impurity such as moisture from the edges can be prevented, whereby the display device **100** can have high reliability and high display quality.

FIG. **18**B**1** is a perspective view of the display device **200** to which the external electrode **124** is connected and which is covered with the layer **147**. FIG. **18**B**2** is a cross-sectional view taken along the dashed-dotted line H**3**-H**4** in FIG. **18**B**1**. In the case where the substrate **111** and the substrate **121** have different external dimensions as in the display device **200**, edges (side surfaces) of one of the substrate **111** and the substrate **121** may be covered with the layer **147**. By covering the side surfaces of at least one of the substrate **111** and the substrate **121** with the layer **147**, an outer periphery of a portion where the substrate **111** and the substrate **121** overlap each other is covered with the layer **147**. Therefore, impurity such as moisture can be prevented from entering the display region **131**, whereby the display device **200** can have high reliability and high display quality. Alternatively, as illustrated in FIG. **18**B**3**, the layer **147** may be provided to cover both of the substrates **111** and **121** having different external dimensions. FIG. **19** is a detailed cross-sectional view taken along the dashed-dotted line H**5**-H**6** in FIG. **18**B**1**.

<Modification Example of Display Device>

FIG. **20**A is a cross-sectional view of the display device **100** including a touch sensor **271** between the substrate **121** and the coloring layer **266**. Specifically, the display device **100** illustrated in FIG. **20**A includes an electrode **272**, an insulating layer **273**, an electrode **274**, and an insulating layer **275** between the insulating layer **145** and the coloring layer **266**. The electrodes **272** and **274** are preferably formed with a light-transmitting conductive material. The insulating layer **273** and the insulating layer **275** can be formed using a material and a method similar to those of the insulating layer **205**. The touch sensor **271** includes the electrode **272** and the electrode **274**. Although an example in which the touch sensor **271** is a capacitance touch sensor is described in this embodiment, the touch sensor **271** may be a resistive touch sensor. Examples of the capacitive touch sensor are of a surface capacitive type and of a projected capacitive type. Alternatively, an active matrix touch sensor using an active element such as a transistor can be used.

Note that a low resistance material is preferably used for a conductive film such as the electrodes **272** and **274**, i.e., a wiring or an electrode, included in the touch sensor. For example, silver, copper, aluminum, a carbon nanotube, graphene, or a metal halide (such as a silver halide) may be used. Alternatively, a metal nanowire including a number of conductors with an extremely small width (for example, a diameter of several nanometers) may be used. Further alternatively, a net-like metal mesh with a conductor may be used. Examples of such materials include: an Ag nanowire, a Cu nanowire, an Al nanowire, an Ag mesh, a Cu mesh, and an Al mesh. In the case of using an Ag nanowire, a light transmittance of 89% or more and a sheet resistance of 40 ohm/square or more and 100 ohm/square or less can be achieved. Since such a material provides a high light transmittance, the metal nanowire, the metal mesh, a carbon nanotube, graphene, or the like may be used for an electrode of the display element, such as a pixel electrode or a common electrode.

Alternatively, one or more of layers each formed using a material having a specific function, such as an anti-reflection layer, a light diffusion layer, a microlens array, a prism sheet, a retardation plate, or a polarizing plate, (hereinafter referred to as "functional layers") may be provided on the outside of the substrate **111** or the substrate **121** through which light **235** is emitted. As the anti-reflection layer, for example, a circularly polarizing plate or the like can be used. With the functional layer, a display device having a higher display quality can be achieved. Moreover, power consumption of the display device can be reduced. As the functional layer, a substrate including the touch sensor **271** may be provided to overlap with the display device **100**.

FIG. **20**B is a cross-sectional view of the display device **100** having a top-emission structure including a functional layer **161**. The functional layer **161** is provided on an outer surface of the substrate **121**. Note that in the case where the display device **100** has a bottom-emission structure, the functional layer **161** may be provided on an outer surface of the substrate **111**. In the case where the display device **100** has a dual-emission structure, the functional layers **161** may be provided on the outer surfaces of the substrate **111** and the substrate **121**.

For the substrate **111** or the substrate **121**, a material having a specific function may be used. For example, a circularly polarizing plate may be used as the substrate **111** or the substrate **121**. Alternatively, for example, the substrate **111** or the substrate **121** may be formed using a retardation plate, and a polarizing plate may be provided so as to overlap with the substrate. As another example, the substrate **111** or the substrate **121** may be formed using a prism sheet, and a circularly polarizing plate may be provided so as to overlap with the substrate. With the use of the material having a specific function for the substrate **111** or the substrate **121**, improvement of display quality and reduction of the manufacturing cost can be achieved.

As shown in the cross-sectional view of FIG. **21**A, a touch panel **270** including the touch sensor **271** on the substrate **221** may be provided on the outer surface of the display device **100**, and the layer **147** may be provided on the outer surface of the touch panel **270** and the display device **100**. The touch panel **270** can input or output a signal through an external electrode **224**. The display device **100** illustrated in FIG. **21**A has a top emission structure; thus, the touch panel **270** is provided on the substrate **121** side through which the light **235** is emitted. In the case where the display device **100** has a bottom emission structure, the touch panel **270** may be provided on the substrate **111** side. In the case where the display device **100** has a dual emission structure, the touch panel **270** may be provided on the substrate **121** side and/or the substrate **111** side.

As shown in a cross-sectional view of FIG. **21**B, the layer **147** may be provided on the outer surface of the display device **100**, and then the touch panel **270** may be provided on the outer surface of the layer **147**. The display device **100** illustrated in FIG. **21**B has a top emission structure, and the touch panel **270** is provided on the outer surface of the layer **147** on the substrate **121** side through which the light **235** is emitted. In the case where the display device **100** has a bottom emission structure, the touch panel **270** may be provided on the outer surface of the layer **147** on the substrate **111** side. In the case where the display device **100** has a dual emission structure, the touch panel **270** may be provided on the outer surface of the layer **147** on the substrate **121** side and/or on the outer surface of the layer **147** on the substrate **111** side.

In the case where the display device performs monochrome display or the case where the display device is used as a lighting device, the coloring layer **266** is not necessarily provided as illustrated in FIG. **22**A. According to the case, the light-blocking layer **264** and the overcoat layer **268** may be omitted. In the case where the light-emitting element **125** has a micro optical resonator structure to be described later, the coloring layer **266** may be omitted. A semiconductor chip **162** may be provided over the external electrode **124**.

A structure shown in FIG. **22**B may be employed, in which the coloring layer **266**, the light-blocking layer **264**, the overcoat layer **268**, and the like are not provided. In that case, color display can be performed with the use of EL layers **117** having different emission spectra, such as an EL layer **117**A and an EL layer **117**B, for respective pixels. The EL layer **117**A, the EL layer **117**B, and the like may emit light of the respective colors such as red, blue, and green. The non-use of the coloring layer **266** can reduce the amount of light loss. A combination of a micro optical resonator structure which is to be described later, the EL layer **117**A, and the EL layer **117**B can improve the color purity. As shown in FIG. **23**, the coloring layer **266** may be provided over the electrode **118**.

FIG. **24** is a cross-sectional view taken along the dashed-dotted line A**5**-A**6** in FIG. **15**B. In the display device of one embodiment of the present invention, if needed, the semiconductor chip **162** may be provided over a substrate over which a functional element such as a transistor is provided. FIG. **24** illustrates an example in which the semiconductor chip **162** (not illustrated in FIG. **15**B) is provided over the substrate **111**.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 3

In this embodiment, an example of a method for forming the layer **147** by which the thickness t**1** and the thickness t**2** of the layer **147**, which are described in Embodiment 1, are equal to each other is described with reference to FIGS. **25**A to **25**E, FIGS. **26**A to **26**C, and FIGS. **27**A to **27**D.

<Example of Fabricating Method of Display Device>

First, the external electrode **124** is connected to the display device **100**, and then spacers **165** are provided on side surfaces of the display device **100**. FIGS. **25**A and **25**B are a perspective view and a top view, respectively, of the display device **100** provided with the spacer **165**. FIG. **25**C is a cross-sectional view taken along the dashed-dotted line V**3**-V**4** in FIG. **25**B. FIG. **25**D is a cross-sectional view taken along the dashed-dotted line V**5**-V**6** in FIG. **25**B.

FIGS. **25**A to **25**C illustrate an example in which the spacers **165** each having a U-shaped cross section are disposed on three side surfaces of the display device **100**. Specifically, the spacer **165** is provided such that side surfaces of the substrate **111** and the substrate **121** fit into a depressed portion of the spacer **165**.

It is preferable that the thickness t**1**, which is a thickness of the spacer **165** in the direction perpendicular to a surface of the substrate **111**, be equal to the thickness t**2**, which is a thickness of the spacer **165** in the direction perpendicular to a surface of the substrate **121** (see FIG. **25**D). The sum of the thickness t**1**, the thickness t**2**, and a thickness t**3**, which is a thickness of the display device **100**, is referred to as a thickness t. Note that in the case where the bending direction of the display device **100** is determined, the case where the substrates **111** and **121** have different thicknesses, or the like, the thickness t**1** and the thickness t**2** may be different in accordance with the purpose. The thickness t may vary depending on a position on the display device **100**.

The cross-sectional shape of the spacer **165** is not limited to a U shape. For example, as shown in FIG. **25**E, a spacer **165***a* having a Y-shaped cross section may be used instead of the spacer **165** having a U-shaped cross section.

FIGS. **25**A and **25**B illustrate an example in which two or more spacers **165** are provided on each of the three side surfaces of the display device **100**, but the number of the spacers is not limited to this. As shown in FIG. **26**A, one spacer **165** may be disposed on each of the three side surfaces of the display device **100**. At least one spacer **165** is provided on each of the three side surfaces of the display device **100**. Therefore, spacers **165** may be provided on four side surfaces of the display device **100**.

As shown in FIG. **26**B, the spacer **165** may be disposed at each of the four corners of the display device **100**. As shown in FIG. **26**C, part or the whole of the three side surfaces may be covered with the spacer **165**.

As shown in FIGS. **27**A to **27**D, cuboid spacers **165***b* may be provided on the substrate **111** and the substrate **121**. FIGS. **27**A and **27**B are a perspective view and a top view, respectively, of the display device **100** provided with the spacers **165***b*. FIG. **27**C is a cross-sectional view taken along the dashed-dotted line V**7**-V**8** in FIGS. **27**A and **27**B. FIG. **27**D is a cross-sectional view taken along the dashed-dotted line V**9**-V**10** in FIGS. **27**A and **27**B.

Next, the display device **100** provided with the spacers **165** is disposed in the depressed portion **192** of the structure body **191** (see FIG. **28**A). Then, the structure body **193** and the structure body **191** are disposed to overlap each other (see FIG. **28**B). At this time, the display device **100** provided with the spacers **165** is prevented from protruding from the depressed portion **194** of the structure body **193**.

FIG. **29**A is a perspective view illustrating a state where the structure body **191** and the structure body **193** overlap each other with the display device **100** provided with the spacers **165** interposed therebetween. The display device **100** provided with the spacers **165** is disposed in a space formed by the depressed portion **192** and the depressed portion **194**. FIG. **29**B is a cross-sectional view taken along the dashed-dotted line V**11**-V**12** in FIG. **29**A. FIG. **29**C is a cross-sectional view illustrating a state where the display device **100** provided with the spacers **165***a* is disposed in a space formed by the depressed portion **192** and the depressed portion **194**. A distance k of the space is preferably equal to the thickness t.

Next, the liquid filler **195** is put into the space formed by the depressed portion **192** and the depressed portion **194** (see FIG. **30**A). At this time, if the filler **195** has a high viscosity, a gap is generated around the spacer **165**, which reduces the reliability of the display device **100** in some cases. With the use of the filler **195** with a low viscosity, the filler **195** fills spaces around the spacer **165** easily, which can suppress generation of a gap. The viscosity of the filler **195** is preferably lower than or equal to 10 Pa·s (Pascal second), more preferably lower than or equal to 5 Pa·s, and still more preferably lower than or equal to 1 Pa·s.

The filler **195** is cured to have the shape of the depressed portion **192** and the depressed portion **194**, whereby the layer **147** can be formed. After the formation of the layer **147**, the structure body **191** and the structure body **193** are separated (see FIG. **30**B). Note that it is preferable to apply a remover onto surfaces of the depressed portion **192** and the depressed portion **194** before the space is filled with the filler **195**, in which case the layer **147** can be separated easily from the structure body **191** and the structure body **193**.

Note that when a material of the spacer **165**, the spacer **165***a*, and the spacer **165***b* is different from a material of the layer **147**, a difference in refractive index, light transmittance, or the like causes optical distortion in the vicinity of a boundary between the spacer and the layer **147**, which reduces the display quality of the display device **100** in some cases. For this reason, it is preferable that the spacer and the display region **131** do not overlap each other.

For the spacer **165**, the spacer **165***a*, and the spacer **165***b*, a material having the same refractive index, light transmittance, or the like as a material of the layer **147** is preferably used, in which case the spacer and the layer can be bonded to each other without recognition of the boundary. Thus, the display device **100** can have high display quality.

For the spacer **165**, the spacer **165***a*, and the spacer **165***b*, a material having the same composition as a material of the layer **147** is used, in which case a bonding state between the spacer and the layer **147** can be favorable. Thus, impurity can be prevented from entering from a boundary interface, whereby the display device **100** can have high reliability.

For example, a filler that is the same as the filler **195** is used for the spacer **165**, the spacer **165***a*, and the spacer **165***b*, in which case the spacer can have the same composition as the layer **147**. With the use of a material of the spacer **165**, the spacer **165***a*, and the spacer **165***b* having the same composition as the layer **147**, the spacer and the layer can have the same refractive index, light transmittance, and the like. According to the fabricating method described in this embodiment, the layer **147** can be substantially seamless.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 4

In this embodiment, an example of a method for fabricating the display device **100**, which is different from that described in the above embodiments, is described with reference to FIGS. **31**A to **31**C, FIG. **32**A to **32**C, FIG. **33**, FIGS. **34**A to **34**C, FIGS. **35**A and **35**B, FIG. **36**, FIGS. **37**A to **37**C, and FIGS. **38**A and **38**B.

<Example of Fabricating Method of Display Device>

In this embodiment, a method for fabricating the display device **100** is described using a structure body **501** including a depressed portion **502**.

For example, a metallic mold can be used as the structure body **501**. A material used for the structure body **501** is not limited to metal. For example, glass, ceramic, an organic resin, or wood may be used.

FIG. **31**A is a perspective view of the structure body **501**. FIG. **31**B is a cross-sectional view taken along the dashed-dotted line X**1**-X**2** in FIG. **31**A. FIG. **31**C is a cross-sectional view taken along the dashed-dotted line Y**1**-Y**2** in FIG. **31**A. A depth d**1** of the depressed portion **502** is preferably equal to the sum of the thickness t**1** and the thickness t**3** or the sum of the thickness t**2** and the thickness t**3**. For example, when the thickness t**3** is 70 μm and the thickness t**1** is 100 μm, the depth d**1** is preferably 170 m or more.

First, a filler **195***a* is put into the depressed portion **502**. Then, the filler **195***a* is cured to form a layer **511** (see FIG. **32**A). The amount of the filler **195***a* is determined depending on the thickness t**1** of the layer **511** (see FIGS. **32**B and **32**C).

Next, the display device **100** is disposed over the layer **511** (see FIG. **33**). At this time, it is necessary to be careful not to form bubbles between the display device **100** and the layer **511**. FIG. **34**A is a perspective view illustrating a state where the display device **100** is disposed over the layer **511**. FIG. **34**B is a cross-sectional view taken along the dashed-dotted line X**1**-X**2** in FIG. **34**A. FIG. **34**C is a cross-sectional view taken along the dashed-dotted line Y**1**-Y**2** in FIG. **34**A. Although FIGS. **34**A to **34**C illustrates an example where the display device **100** is disposed over the layer **511** such that the substrate **111** of the display device **100** faces the layer **511**, the display device **100** may be disposed such that the substrate **121** faces the layer **511**.

Then, the display device **100** with the layer **511** is separated from the structure body **501** (see FIG. **35**A). Note that FIG. **35**B is a cross-sectional view taken along the dashed-dotted line Y**1**-Y**2** in FIG. **35**A, and illustrates the display device **100** provided over the layer **511**.

Next, a filler **195***b* is put into the depressed portion **502** (see FIG. **36**). Then, the display device **100** with the layer **511** is turned upside down, and the display device **100** is disposed over the filler **195***b* such that the substrate **121** of the display device **100** faces the filler **195***b*. At this time, attention is necessary not to form bubbles between the display device **100** and the filler **195***b*. Note that in the case where the substrate **121** and the layer **511** are disposed to face each other in the previous step, the display device **100** is disposed over the filler **195***b* such that the substrate **111** faces the filler **195***b*.

FIG. **37**A is a perspective view illustrating a state where the display device **100** is disposed over the filler **195***b* in the depressed portion **502**. FIG. **37**B is a cross-sectional view taken along the dashed-dotted line X**1**-X**2** in FIG. **37**A. FIG. **37**C is a cross-sectional view taken along the dashed-dotted line Y**1**-Y**2** in FIG. **37**A. The thickness t**2** is determined by the amount of the filler **195***b* (see FIG. **38**B). The amount of the filler **195***b* may be determined as long as at least the edges of the substrate **111** and the substrate **121** are covered with the filler **195***b*.

Then, the filler **195***b* is cured. The cured filler **195***b* and the layer **511** are bonded to be seamless, whereby the layer **147** is formed. After the formation of the layer **147**, the layer **147** and the display device **100** are taken out of the structure body **501** (see FIG. **38**A). FIG. **38**B is a cross-sectional view taken along the dashed-dotted line Y**1**-Y**2** in FIG. **38**A.

The material used as the filler **195** can be used as the filler **195***a* and the filler **195***b*. The filler **195***a* and the filler **195***b* can be different materials. However, with the use of the same material as the filler **195***a* and the filler **195***b*, bonding therebetween after being cured can be favorable. According to the fabricating method described in this embodiment, the layer **147** can be substantially seamless.

Thus, the display device **100** can be covered with the layer **147**. With the layer **147** that covers the display device **100**, the display device is less likely to be broken even when being bent and extended repeatedly. By covering the edges of the substrate **111** and the substrate **121** with the layer **147**, entry of impurity such as moisture from the edges can be prevented, whereby the display device **100** can have high reliability and high display quality. The seamless layer **147** covering the display device **100** can further increase the reliability of the display device **100**.

By the fabricating method described in this embodiment, the layer **147** can be formed with fewer materials and fewer structure bodies than by the fabricating method described in Embodiment 2. Note that the fabricating method described in this embodiment is particularly effective in forming the layer **147** to be thin, for example, in the case where the thickness t**1** or the thickness t**2** is less than or equal to 1 mm, preferably less than or equal to 500 μm. The fabricating method described in this embodiment can reduce materials for forming the layer **147**. The fabricating method of one embodiment of the present invention can improve the productivity of the display device. In addition, the productivity of a semiconductor device including the display device can be improved.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 5

In this embodiment, an example of a method for fabricating the display device **100** covered with the layer **147**, which is different from that described in the above embodiments, is described with reference to FIGS. **39**A to **39**C, FIG. **40**A to **40**C, FIG. **41**, FIGS. **42**A to **42**C, FIGS. **43**A to **43**C, and FIGS. **44**A and **44**B.

<Example of Fabricating Method of Display Device>

In this embodiment, a method for fabricating the display device **100** covered with the layer **147** is described using a structure body **551** including a depressed portion **552**.

For example, a metallic mold can be used as the structure body **551**. A material used for the structure body **551** is not limited to metal. For example, glass, ceramic, an organic resin, or wood may be used.

FIG. **39**A is a perspective view of the structure body **551**. FIG. **39**B is a cross-sectional view taken along the dashed-dotted line X**3**-X**4** in FIG. **39**A. FIG. **39**C is a cross-sectional view taken along the dashed-dotted line Y**3**-Y**4** in FIG. **39**A. A depth d**2** of the depressed portion **552** is preferably greater than or equal to the thickness t. For example, when the thickness t**3** is 70 m and the thickness t**1** and the thickness t**2** are each 100 μm, the depth d**2** is preferably 270 m or more.

First, the filler **195***a* is put into the depressed portion **552**. Then, the filler **195***a* is cured to form a layer **511** (see FIG. **40**A). The amount of the filler **195***a* is determined depending on the thickness t**1** of the layer **511** (see FIGS. **40**B and **40**C).

Next, the display device **100** is disposed over the layer **511** in the depressed portion **552** (see FIG. **41**). At this time, it is necessary to be careful not to form bubbles between the display device **100** and the layer **511**. FIG. **42**A is a perspective view illustrating a state where the display device **100** is disposed over the layer **511**. FIG. **42**B is a cross-sectional view taken along the dashed-dotted line X**3**-X**4** in FIG. **42**A. FIG. **42**C is a cross-sectional view taken along the dashed-dotted line Y**3**-Y**4** in FIG. **42**A. Although FIGS. **42**A to **42**C illustrates an example where the display device **100** is disposed over the layer **511** such that the substrate **111** of the display device **100** faces the layer **511**, the display device **100** may be disposed such that the substrate **121** faces the layer **511**.

Next, the depressed portion **552** is filled with the filler **195***b*, whereby the display device **100** is covered with the filler **195***b*. FIG. **43**A is a perspective view illustrating a state where the depressed portion **552** is filled with the filler **195***b*. FIG. **43**B is a cross-sectional view taken along the dashed-dotted line X**3**-X**4** in FIG. **43**A. FIG. **43**C is a cross-sectional view taken along the dashed-dotted line Y**3**-Y**4** in FIG. **43**A. The thickness t**2** is determined by the amount of the filler **195***b* (see FIG. **44**B). The amount of the filler **195***b* may be determined as long as at least the edges of the substrate **111** and the substrate **121** are covered with the filler **195***b*.

Then, the filler **195***b* is cured. The cured filler **195***b* and the layer **511** are bonded to be seamless, whereby the layer **147** is formed. After the formation of the layer **147**, the layer **147** and the display device **100** are taken out of the structure body **551** (see FIG. **44**A). FIG. **44**B is a cross-sectional view taken along the dashed-dotted line Y**3**-Y**4** in FIG. **44**A.

As described in the above embodiment, the material used as the filler **195** can be used as the filler **195***a* and the filler **195***b*. The filler **195***a* and the filler **195***b* can be different materials. However, with the use of the same material as the filler **195***a* and the filler **195***b*, bonding therebetween after being cured can be favorable. According to the fabricating method described in this embodiment, the layer **147** can be substantially seamless.

Thus, the display device **100** can be covered with the layer **147**. With the layer **147** that covers the display device **100**, the display device is less likely to be broken even when being bent and extended repeatedly. Since the layer **147** that covers the display device **100** is seamless, by covering the edges of the substrate **111** and the substrate **121** with the layer **147**, entry of impurity such as moisture from the edges can be prevented, whereby the display device **100** can have high reliability and high display quality. The seamless layer **147** covering the display device **100** can further increase the reliability of the display device **100**.

By the fabricating method described in this embodiment, the layer **147** can be formed with fewer materials and fewer structure bodies than by the fabricating method described in Embodiment 2. Note that the fabricating method described in this embodiment is particularly effective in forming the layer **147** to be thin, for example, in the case where the thickness t**1** or the thickness t**2** is less than or equal to 1 mm, preferably less than or equal to 500 μm. The fabricating method described in this embodiment can reduce materials for forming the layer **147**. The fabricating method of one embodiment of the present invention can improve the productivity of the display device. In addition, the productivity of a semiconductor device including the display device can be improved.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 6

In this embodiment, a structure example of a transistor that can be used in place of the transistor described in the above embodiments will be described with reference to FIG. **45A1** to FIG. **49**C.

[Bottom-Gate Transistor]

A transistor **410** shown in FIG. **45A1** as an example is a channel-protective transistor that is a type of bottom-gate transistor. The transistor **410** includes an electrode **246** that can function as a gate electrode over an insulating layer **109**. The transistor **410** includes a semiconductor layer **242** over the electrode **246** with an insulating layer **116** positioned therebetween. The electrode **246** can be formed using a material and a method similar to those of the gate electrode **206**.

The transistor **410** includes an insulating layer **209** that can function as a channel protective layer over a channel formation region in the semiconductor layer **242**. The insulating layer **209** can be formed using a material and a method similar to those of the insulating layer **116**. Part of the electrode **244** and part of the electrode **245** are formed over the insulating layer **209**.

With the insulating layer **209** provided over the channel formation region, the semiconductor layer **242** can be prevented from being exposed at the time of forming the electrode **244** and the electrode **245**. Thus, the semiconductor layer **242** can be prevented from being reduced in thickness at the time of forming the electrode **244** and the electrode **249**. With one embodiment of the present invention, a transistor with favorable electrical characteristics can be provided.

A transistor **411** illustrated in FIG. **45**A**2** is different from the transistor **410** in that an electrode **213** that can function as a back gate electrode is provided over an insulating layer **119**. The electrode **213** can be formed using a material and a method that are similar to those of the gate electrode **206**.

In general, the back gate electrode is formed using a conductive layer and positioned so that the channel formation region of the semiconductor layer is provided between the gate electrode and the back gate electrode. Thus, the back gate electrode can function in a manner similar to that of the gate electrode. The potential of the back gate electrode may be the same as that of the gate electrode or may be a GND potential or a predetermined potential. By changing a potential of the back gate electrode independently of the potential of the gate electrode, the threshold voltage of the transistor can be changed.

The electrodes **246** and **213** can both function as a gate electrode. Thus, the insulating layers **116**, **209**, and **119** can all function as a gate insulating layer.

In the case where one of the electrode **246** and the electrode **213** is simply referred to as a "gate electrode", the other can be referred to as a "back gate electrode". For example, in the transistor **411**, in the case where the electrode **213** is referred to as a "gate electrode", the electrode **246** is referred to as a "back gate electrode". In the case where the electrode **213** is used as a "gate electrode", the transistor **411** is a kind of bottom-gate transistor. Furthermore, one of the electrode **246** and the electrode **213** may be referred to as a "first gate electrode", and the other may be referred to as a "second gate electrode".

By providing the electrode **246** and the electrode **213** with the semiconductor layer **242** provided therebetween and setting the potentials of the electrode **246** and the electrode **213** to be the same, a region of the semiconductor layer **242** through which carriers flow is enlarged in the film thickness direction; thus, the number of transferred carriers is increased. As a result, the on-state current and the field-effect mobility of the transistor **411** are increased.

Therefore, the transistor **411** has large on-state current for the area occupied thereby. That is, the area occupied by the transistor **411** can be small for required on-state current. With one embodiment of the present invention, the area occupied by a transistor can be reduced. Therefore, with one embodiment of the present invention, a highly integrated semiconductor device can be provided.

Furthermore, the gate electrode and the back gate electrode are formed using conductive layers and thus each have a function of preventing an electric field generated outside the transistor from influencing the semiconductor layer in which the channel is formed (in particular, an electric field blocking function against static electricity and the like). When the back gate electrode is formed larger than the semiconductor layer such that the semiconductor layer is covered with the back gate electrode, the electric field blocking function can be enhanced.

Since the electrode **246** and the electrode **213** each have a function of blocking an electric field generated outside, charges of charged particles and the like generated on the insulating layer **109** side or above the electrode **213** do not influence the channel formation region in the semiconductor layer **242**. Therefore, degradation in a stress test (e.g., a negative gate bias temperature (−GBT) stress test in which negative charges are applied to a gate) can be reduced, and changes in the rising voltages of on-state current at different drain voltages can be suppressed. Note that this effect is caused when the electrodes **246** and **213** have the same potential or different potentials.

The BT stress test is one kind of accelerated test and can evaluate, in a short time, a change by long-term use (i.e., a change over time) in characteristics of transistors. In particular, the change in threshold voltage of the transistor between before and after the BT stress test is an important indicator when examining the reliability of the transistor. If the change in the threshold voltage between before and after the BT stress test is small, the transistor has higher reliability.

By providing the electrode **246** and the electrode **213** and setting the potentials of the electrode **246** and the electrode **213** to be the same, the change in threshold voltage is reduced. Accordingly, variation in electrical characteristics among a plurality of transistors is also reduced.

The transistor including the back gate electrode has a smaller change in threshold voltage between before and after a positive GBT stress test in which positive charges are applied to a gate than a transistor including no back gate electrode.

When the back gate electrode is formed using a light-blocking conductive film, light can be prevented from entering the semiconductor layer from the back gate electrode side. Therefore, photodegradation of the semiconductor layer can be prevented and deterioration in electrical characteristics of the transistor, such as a shift of the threshold voltage, can be prevented.

With one embodiment of the present invention, a transistor with high reliability can be provided. Moreover, a semiconductor device with high reliability can be provided.

A transistor **420** shown in FIG. **45B1** as an example is a channel-protective transistor that is a type of bottom-gate transistor. The transistor **420** has substantially the same structure as the transistor **410** but is different from the transistor **410** in that the insulating layer **209** covers the semiconductor layer **242**. The semiconductor layer **242** is electrically connected to the electrode **244** in an opening which is formed by selectively removing part of the insulating layer **209** overlapping with the semiconductor layer **242**. The semiconductor layer **242** is electrically connected to the electrode **245** in the opening which is formed by selectively removing part of the insulating layer **209** overlapping with the semiconductor layer **242**. A region of the insulating layer **209** which overlaps with the channel formation region can function as a channel protective layer.

A transistor **421** illustrated in FIG. **45**B**2** is different from the transistor **420** in that the electrode **213** that can function as a back gate electrode is provided over the insulating layer **119**.

With the insulating layer **209**, the semiconductor layer **242** can be prevented from being exposed at the time of forming the electrode **244** and the electrode **245**. Thus, the semiconductor layer **242** can be prevented from being reduced in thickness at the time of forming the electrode **244** and the electrode **245**.

The length between the electrode **244** and the electrode **246** and the length between the electrode **245** and the electrode **246** in the transistors **420** and **421** are longer than those in the transistors **410** and **411**. Thus, the parasitic capacitance generated between the electrode **244** and the electrode **246** can be reduced. Moreover, the parasitic capacitance generated between the electrode **245** and the electrode **246** can be reduced.

[Top-Gate Transistor]

A transistor **430** shown in FIG. **46A1** as an example is a type of top-gate transistor. The transistor **430** includes the semiconductor layer **242** over the insulating layer **109**; the electrode **244** in contact with part of the semiconductor layer **242** and the electrode **245** in contact with part of the semiconductor layer **242**, over the semiconductor layer **242** and the insulating layer **109**; the insulating layer **116** over the semiconductor layer **242** and the electrodes **244** and **245**; and the electrode **246** over the insulating layer **116**.

Since, in the transistor **430**, the electrode **246** overlaps with neither the electrode **244** nor the electrode **245**, the parasitic capacitance generated between the electrode **246** and the electrode **244** and the parasitic capacitance generated between the electrode **246** and the electrode **245** can be reduced. After the formation of the electrode **246**, an impurity element **255** is added to the semiconductor layer **242** using the electrode **246** as a mask, so that an impurity region can be formed in the semiconductor layer **242** in a self-aligned manner (see FIG. **46A3**). With one embodiment of the present invention, a transistor with favorable electrical characteristics can be provided.

The introduction of the impurity element **255** can be performed with an ion implantation apparatus, an ion doping apparatus, or a plasma treatment apparatus.

As the impurity element **255**, for example, at least one element of a Group 13 element and a Group 15 element can be used. In the case where an oxide semiconductor is used for the semiconductor layer **242**, it is possible to use at least one kind of element of a rare gas, hydrogen, and nitrogen as the impurity element **255**.

A transistor **431** illustrated in FIG. **46A2** is different from the transistor **430** in that the electrode **213** and an insulating layer **217** are included. The transistor **431** includes the electrode **213** formed over the insulating layer **109** and the insulating layer **217** formed over the electrode **213**. As described above, the electrode **213** can function as a back gate electrode. Thus, the insulating layer **217** can function as a gate insulating layer. The insulating layer **217** can be formed using a material and a method that are similar to those of the insulating layer **205**.

The transistor **431** as well as the transistor **411** has large on-state current for the area occupied thereby. That is, the area occupied by the transistor **431** can be small for required on-state current. With one embodiment of the present invention, the area occupied by a transistor can be reduced. Therefore, with one embodiment of the present invention, a semiconductor device having a high degree of integration can be provided.

A transistor **440** shown in FIG. **46B1** as an example is a type of top-gate transistor. The transistor **440** is different from the transistor **430** in that the semiconductor layer **242** is formed after the formation of the electrode **244** and the electrode **245**. A transistor **441** shown in FIG. **46B2** as an example is different from the transistor **440** in that it includes the electrode **213** and the insulating layer **217**. Thus, in the transistors **440** and **441**, part of the semiconductor layer **242** is formed over the electrode **244** and another part of the semiconductor layer **242** is formed over the electrode **245**.

The transistor **441** as well as the transistor **411** has large on-state current for the area occupied thereby. That is, the area occupied by the transistor **441** can be small for required on-state current. With one embodiment of the present invention, the area occupied by a transistor can be reduced. Therefore, with one embodiment of the present invention, a semiconductor device having a high degree of integration can be provided.

In the transistors **440** and **441**, after the formation of the electrode **246**, the impurity element **255** is added to the semiconductor layer **242** using the electrode **246** as a mask, so that an impurity region can be formed in the semiconductor layer **242** in a self-aligned manner.

[S-Channel Transistor]

FIGS. **47**A to **47**C illustrate an example of a structure of a transistor including an oxide semiconductor layer as the semiconductor layer **242**. In a transistor **450** illustrated in FIGS. **47**A to **47**C, a semiconductor layer **242*b*** is formed over a semiconductor layer **242*a***, and a semiconductor layer **242*c*** covers a top surface and a side surface of the semiconductor layer **242*b*** and a side surface of the semiconductor layer **242*a***. FIG. **47**A is a top view of the transistor **450**. FIG. **47**B is a cross-sectional view (in the channel length direction) taken along the dashed-dotted line **X1**-**X2** in FIG. **47**A. FIG. **47**C is a cross-sectional view (in the channel width direction) taken along the dashed-dotted line **Y1**-**Y2** in FIG. **47**A.

Each of the semiconductor layer **242*a***, the semiconductor layer **242*b***, and the semiconductor layer **242*c*** is formed using a material containing either In or Ga or both of them. Typical examples are an In—Ga oxide (an oxide containing In and Ga), an In—Zn oxide (an oxide containing In and Zn), and an In-M-Zn oxide (an oxide containing In, an element M, and Zn: the element M is one or more kinds of elements selected from Al, Ti, Ga, Y, Zr, La, Ce, Nd, and Hf and corresponds to a metal element whose strength of bonding with oxygen is higher than that of In).

The semiconductor layer **242*a*** and the semiconductor layer **242*c*** are preferably formed using a material containing one or more kinds of metal elements contained in the semiconductor layer **242*b***. With use of such a material, interface states at interfaces between the semiconductor layer **242*a*** and the semiconductor layer **242*b*** and between the semiconductor layer **242*c*** and the semiconductor layer **242*b*** are less likely to be generated. Accordingly, carriers are not likely to be scattered or captured at the interfaces, which results in an improvement in field-effect mobility of the transistor. Further, threshold-voltage variation of the transistor can be reduced. Thus, a semiconductor device having favorable electrical characteristics can be obtained.

Each of the thicknesses of the semiconductor layer **242*a*** and the semiconductor layer **242*c*** is greater than or equal to 3 nm and less than or equal to 100 nm, preferably greater than or equal to 3 nm and less than or equal to 50 nm. The thickness of the semiconductor layer **242*b*** is greater than or equal to 3 nm and less than or equal to 200 nm, preferably greater than or equal to 3 nm and less than or equal to 100 nm, further preferably greater than or equal to 3 nm and less than or equal to 50 nm.

In the case where the semiconductor layer **242*b*** is an In-M-Zn oxide and the semiconductor layer **242*a*** and the semiconductor layer **242*c*** are each an In-M-Zn oxide, the semiconductor layer **242*a*** and the semiconductor layer **242*c*** each have the atomic ratio where In:M:Zn=x_1:y_1:z_1, and the semiconductor layer **242*b*** has an atomic ratio where In:M:Zn=x_2:y_2:z_2, for example. In that case, the compositions of the semiconductor layer **242*a***, the semiconductor layer **242*c***, and the semiconductor layer **242*b*** are determined so that y_1/x_1 is large than y_2/x_2. It is preferable that the compositions of the semiconductor layer **242*a***, the semiconductor layer **242*c***, and the semiconductor layer **242*b*** are determined so that y_1/x_1 is 1.5 times or more as large as y_2/x_2. It is further preferable that the compositions of the semiconductor layer **242*a***, the semiconductor layer **242*c***, and the semiconductor layer **242*b*** are determined so that

y_1/x_1 is twice or more as large as y_2/x_2. It is still further preferable that the compositions of the semiconductor layer **242**a, the semiconductor layer **242**c, and the semiconductor layer **242**b are determined so that y_1/x_1 is three times or more as large as y_2/x_2. At this time, y_1 is preferably greater than or equal to x_1 in the semiconductor layer **242**b, in which case stable electrical characteristics of a transistor can be achieved. However, when y_1 is three times or more as large as x_1, the field-effect mobility of the transistor is reduced; accordingly, y_1 is preferably smaller than three times x_1. When the semiconductor layer **242**a and the semiconductor layer **242**c have the above compositions, the semiconductor layer **242**a and the semiconductor layer **242**c can each be a layer in which oxygen vacancies are less likely to be generated than that in the semiconductor layer **242**b.

In the case where the semiconductor layer **242**a and the semiconductor layer **242**c are each an In-M-Zn oxide, the percentages of contained In and an element M, not taking Zn and O into consideration, is preferably as follows: the content percentage of In is lower than 50 atomic % and the percentage of M is higher than or equal to 50 atomic %. The content percentages of In and M are further preferably as follows: the content percentage of In is lower than 25 atomic % and the content percentage of M is higher than or equal to 75 atomic %. In the case of using an In-M-Zn oxide for semiconductor layer **242**b, the content percentages of In and element M, not taking Zn and O into consideration, are preferably such that the percentage of In is higher than or equal to 25 atomic % and the percentage of M is lower than 75 atomic %. The content percentages In and element M are further preferably such that the percentage of In is higher than or equal to 34 atomic % and the percentage of M is lower than 66 atomic %.

For example, an In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:3:2, 1:3:4, 1:3:6, 1:6:4, or 1:9:6 or an In—Ga oxide which is formed using a target having an atomic ratio of In:Ga=1:9 can be used for each of the semiconductor layer **242**a and the semiconductor layer **242**c containing In or Ga. Furthermore, an In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=3:1:2, 1:1:1, 5:5:6, or 4:2:4.1 can be used for the semiconductor layer **242**b. Note that the atomic ratio of each of the semiconductor layers **242**a, **242**b, and **242**c may vary within a range of ±20% of any of the above-described atomic ratios as an error.

In order to give stable electrical characteristics to the transistor including the semiconductor layer **242**b, it is preferable that impurities and oxygen vacancies in the semiconductor layer **242**b be reduced to obtained a highly purified semiconductor layer; accordingly, the semiconductor layer **242**b can be regarded as an intrinsic or substantially intrinsic semiconductor layer. Furthermore, it is preferable that at least the channel formation region of the semiconductor layer **242**b be regarded as an intrinsic or substantially intrinsic semiconductor layer.

Note that the substantially intrinsic oxide semiconductor layer refers to an oxide semiconductor layer in which the carrier density is lower than $1\times10^{17}/cm^3$, lower than $1\times10^{15}/cm^3$, or lower than $1\times10^{13}/cm^3$.

[Energy Band Structure of Oxide Semiconductor]

The function and effect of the semiconductor layer **242** that is a stacked layer including the semiconductor layer **242**a, the semiconductor layer **242**b, and the semiconductor layer **242**c is described with an energy band structure diagram shown in FIG. **50**. FIG. **50** is the energy band structure diagram showing a portion along dashed-dotted line D**1**-D**2** in FIG. **47**B. Thus, FIG. **50** shows the energy band structure of a channel formation region of the transistor **450**.

In FIG. **50**, Ec**382**, Ec**383**a, Ec**383**b, Ec**383**c, and Ec**386** are the energies of bottoms of the conduction band in the insulating layer **109**, the semiconductor layer **242**a, the semiconductor layer **242**b, the semiconductor layer **242**c, and the insulating layer **116**, respectively.

Here, a difference in energy between the vacuum level and the bottom of the conduction band (the difference is also referred to as "electron affinity") corresponds to a value obtained by subtracting an energy gap from a difference in energy between the vacuum level and the top of the valence band (the difference is also referred to as an ionization potential). Note that the energy gap can be measured using a spectroscopic ellipsometer (UT-300 manufactured by HORIBA JOBIN YVON S.A.S.). The energy difference between the vacuum level and the top of the valence band can be measured using an ultraviolet photoelectron spectroscopy (UPS) device (VersaProbe manufactured by ULVAC-PHI, Inc.).

Note that an In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:3:2 has an energy gap of approximately 3.5 eV and an electron affinity of approximately 4.5 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:3:4 has an energy gap of approximately 3.4 eV and an electron affinity of approximately 4.5 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:3:6 has an energy gap of approximately 3.3 eV and an electron affinity of approximately 4.5 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:6:2 has an energy gap of approximately 3.9 eV and an electron affinity of approximately 4.3 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:6:8 has an energy gap of approximately 3.5 eV and an electron affinity of approximately 4.4 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:6:10 has an energy gap of approximately 3.5 eV and an electron affinity of approximately 4.5 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=1:1:1 has an energy gap of approximately 3.2 eV and an electron affinity of approximately 4.7 eV. An In—Ga—Zn oxide which is formed using a target having an atomic ratio of In:Ga:Zn=3:1:2 has an energy gap of approximately 2.8 eV and an electron affinity of approximately 5.0 eV.

Since the insulating layer **109** and the insulating layer **116** are insulators, Ec**382** and Ec**386** are closer to the vacuum level (have a smaller electron affinity) than Ec**383**a, Ec**383**b, and Ec**383**c.

Further, Ec**383**a is closer to the vacuum level than Ec**383**b. Specifically, Ec**383**a is preferably located closer to the vacuum level than Ec**383**b by 0.05 eV or more, 0.07 eV or more, 0.1 eV or more, or 0.15 eV or more and 2 eV or less, 1 eV or less, 0.5 eV or less, or 0.4 eV or less.

Further, Ec**383**c is closer to the vacuum level than Ec**383**b. Specifically, Ec**383**c is preferably located closer to the vacuum level than Ec**383**b by 0.05 eV or more, 0.07 eV or more, 0.1 eV or more, or 0.15 eV or more and 2 eV or less, 1 eV or less, 0.5 eV or less, or 0.4 eV or less.

In the vicinity of the interface between the semiconductor layer **242**a and the semiconductor layer **242**b and the vicinity of the interface between the semiconductor layer **242**b and the semiconductor layer **242**c, mixed regions are formed; thus, the energy of the bottom of the conduction band continuously changes. In other words, no state or few states exist at these interfaces.

Accordingly, electrons transfer mainly through the semiconductor layer **242***b* in the stacked-layer structure having the above energy band structure. Therefore, even when an interface state exists at an interface between the semiconductor layer **242***a* and the insulating layer **109** or an interface between the semiconductor layer **242***c* and the insulating layer **116**, the interface state hardly influences the transfer of the electrons. In addition, the interface state does not exist or hardly exists at an interface between the semiconductor layer **242***a* and the semiconductor layer **242***b* and at an interface between the semiconductor layer **242***c* and the semiconductor layer **242***b*; thus, transfer of electrons are not prohibited in the region. Consequently, the transistor **450** having the above stacked oxide semiconductors can have high field-effect mobility.

Note that although trap states **390** due to impurities or defects might be formed in the vicinity of the interface between the semiconductor layer **242***a* and the insulating layer **109** and in the vicinity of the interface between the semiconductor layer **242***c* and the insulating layer **116** as shown in FIG. **50**, the semiconductor layer **242***b* can be separated from the trap states owing to the existence of the semiconductor layer **242***a* and the semiconductor layer **242***c*.

In particular, in the transistor **450** described in this embodiment, an upper surface and a side surface of the semiconductor layer **242***b* are in contact with the semiconductor layer **242***c*, and a bottom surface of the semiconductor layer **242***b* is in contact with the semiconductor layer **242***a*. In this manner, the semiconductor layer **242***b* is surrounded by the semiconductor layer **242***a* and the semiconductor layer **242***c*, whereby the influence of the trap state can be further reduced.

However, in the case where an energy difference between Ec**383***a* or Ec**383***c* and Ec**383***b* is small, electrons in the semiconductor layer **242***b* might reach the trap states by passing over the energy gap. The electrons are trapped by the trap states, which generates a negative fixed charge at the interface with the insulating layer, causing the threshold voltage of the transistor to be shifted in the positive direction.

Therefore, each of the energy differences between Ec**383***a* and Ec**383***b* and between Ec**383***c* and Ec**383***b* is preferably set to be greater than or equal to 0.1 eV, further preferably greater than or equal to 0.15 eV, in which case a change in the threshold voltage of the transistor can be reduced and the transistor can have favorable electrical characteristics.

Each of the band gaps of the semiconductor layer **242***a* and the semiconductor layer **242***c* is preferably larger than that of the semiconductor layer **242***b*.

With one embodiment of the present invention, a transistor with a small variation in electrical characteristics can be provided. Accordingly, a semiconductor device with a small variation in electrical characteristics can be provided. With one embodiment of the present invention, a transistor with high reliability can be provided. Accordingly, a semiconductor device with high reliability can be provided.

An oxide semiconductor has a band gap of 2 eV or more; therefore, a transistor including an oxide semiconductor in a semiconductor layer in which a channel is formed has an extremely small amount of off-state current. Specifically, the off-state current per micrometer of channel width at room temperature can be less than 1×10^{-20} A, preferably less than 1×10^{-22} A, further preferably less than 1×10^{-24} A. That is, the on/off ratio of the transistor can be greater than or equal to 20 digits and less than or equal to 150 digits.

With one embodiment of the present invention, a transistor with low power consumption can be provided. Accordingly, a semiconductor device or an imaging device with low power consumption can be provided.

A transistor using an oxide semiconductor in a semiconductor layer (also referred to as an OS transistor) has a significantly low off-state current. Therefore, for example, when an OS transistor is used as the transistor **431**, the capacitor **233** can be small. Alternatively, parasitic capacitance of the transistor or the like can be used instead of the capacitor **233** without providing the capacitor **233**. Therefore, an area occupied by the pixels **130** can be reduced, which leads to high definition of the display region **131**, whereby the display quality of the display device **100** can be improved. Moreover, power consumption of the display device **100** can be reduced. In addition, the display device **100** with high reliability can be provided.

The transistor **450** illustrated in FIGS. **47**A to **47**C is described again. A semiconductor layer **242***b* is provided over a projecting portion of the insulating layer **109**, in which case the electrode **243** can cover a side surface of the semiconductor layer **242***b*. That is, the transistor **450** has a structure in which the semiconductor layer **242***b* is electrically surrounded by an electric field of the electrode **243**. Such a structure of a transistor in which a semiconductor layer where a channel is formed is electrically surrounded by an electric field of a conductive film is referred to as a surrounded channel (s-channel) structure. A transistor having an s-channel structure is referred to as an s-channel transistor.

In the s-channel transistor, a channel is formed in the whole (bulk) of the semiconductor layer **242***b* in some cases. In the s-channel transistor, the drain current of the transistor can be increased, so that a larger amount of on-state current can be obtained. Furthermore, the entire channel formation region of the semiconductor layer **242***b* can be depleted by the electric field of the electrode **243**. Accordingly, the off-state current of the s-channel transistor can be further reduced.

When the projecting portion of the insulating layer **109** is increased in height, and the channel width is shortened, the effects of the s-channel structure to increase the on-state current and reduce the off-state current can be enhanced. Part of the semiconductor layer **242***a* exposed in the formation of the semiconductor layer **242***b* may be removed. In this case, the side surfaces of the semiconductor layer **242***a* and the semiconductor layer **242***b* are aligned to each other in some cases.

As in a transistor **451** illustrated in FIGS. **48**A to **48**C, the electrode **213** may be provided under the semiconductor layer **242** with an insulating layer positioned therebetween. FIG. **48**A is a top view of a transistor **451**. FIG. **48**B is a cross-sectional view taken along the dashed-dotted line **X1**-**X2** in FIG. **48**A. FIG. **48**C is a cross-sectional view taken along the dashed-dotted line **Y1**-**Y2** in FIG. **48**A.

As in the transistor **452** illustrated in FIGS. **49**A to **49**C, a layer **214** may be provided over the electrode **243**. FIG. **49**A is a top view of the transistor **452**. FIG. **49**B is a cross-sectional view taken along the dashed-dotted line **X1**-**X2** in FIG. **49**A. FIG. **49**C is a cross-sectional view taken along the dashed-dotted line **Y1**-**Y2** in FIG. **49**A.

Although the layer **214** is provided over the insulating layer **211** in FIGS. **49**A to **49**C, the layer **214** may be provided over the insulating layer **119**. The layer **214** formed with a material with a light-blocking property can prevent a change in transistor characteristics, a decrease in reliability, or the like caused by light irradiation. In the case where the layer **214** is formed larger than at least the semiconductor layer **242***b* and covers the semiconductor layer **242***b*, the above-described effects can be enhanced. The layer **214** can be formed with an organic material, an inorganic material, or a metal material. In the case where the layer **214** is formed with a conductive material, the layer **214** may be supplied with voltage or may be electrically floating.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 7

In this embodiment, structure examples of a light-emitting element that can be applied to the light-emitting element **125** are described. Note that an EL layer **320** described in this embodiment corresponds to the EL layer **117** described in the above embodiment.

<Structure of Light-Emitting Element>

In a light-emitting element **330** illustrated in FIG. **51**A, the EL layer **320** is interposed between a pair of electrodes (an electrode **318** and an electrode **322**). Note that the electrode **318** is used as an anode and the electrode **322** is used as a cathode as an example in the following description of this embodiment.

The EL layer **320** includes at least a light-emitting layer and may have a stacked-layer structure including a functional layer other than the light-emitting layer. As the functional layer other than the light-emitting layer, a layer containing a substance having a high hole-injection property, a substance having a high hole-transport property, a substance having a high electron-transport property, a substance having a high electron-injection property, a bipolar substance (a substance having high electron- and hole-transport properties), or the like can be used. Specifically, functional layers such as a hole-injection layer, a hole-transport layer, an electron-transport layer, and an electron-injection layer can be used in combination as appropriate.

The light-emitting element **330** illustrated in FIG. **51**A emits light when current flows because of a potential difference applied between the electrode **318** and the electrode **322** and holes and electrons are recombined in the EL layer **320**. That is, the light-emitting region is formed in the EL layer **320**.

In the present invention, light emitted from the light-emitting element **330** is extracted to the outside from the electrode **318** side or the electrode **322** side. Therefore, one of the electrode **318** and the electrode **322** is formed of a light-transmitting substance.

Note that a plurality of EL layers **320** may be stacked between the electrode **318** and the electrode **322** as in a light-emitting element **331** illustrated in FIG. **51**B. In the case where n (n is a natural number of 2 or more) layers are stacked, a charge generation layer **320***a* is preferably provided between an m-th EL layer **320** and an (m+1)-th EL layer **320**. Note that m is a natural number greater than or equal to 1 and less than n.

The charge generation layer **320***a* can be formed using a composite material of an organic compound and a metal oxide, a metal oxide, a composite material of an organic compound and an alkali metal, an alkaline earth metal, or a compound thereof; alternatively, these materials can be combined as appropriate. Examples of the composite material of an organic compound and a metal oxide include composite materials of an organic compound and a metal oxide such as vanadium oxide, molybdenum oxide, and tungsten oxide. As the organic compound, a variety of compounds can be used; for example, low molecular compounds such as an aromatic amine compound, a carbazole derivative, and aromatic hydrocarbon and oligomers, dendrimers, and polymers of these low molecular compounds. As the organic compound, it is preferable to use the organic compound which has a hole-transport property and has a hole mobility of 10^{-6} cm^2/Vs or higher. However, substances other than the substances given above may also be used as long as the substances have hole-transport properties higher than electron-transport properties. These materials used for the charge generation layer **320***a* have excellent carrier-injection properties and carrier-transport properties; thus, the light-emitting element **330** can be driven with low current and with low voltage.

Note that the charge generation layer **320***a* may be formed with a combination of a composite material of an organic compound and a metal oxide with another material. For example, a layer containing a composite material of the organic compound and the metal oxide may be combined with a layer containing a compound of a substance selected from substances with an electron-donating property and a compound with a high electron-transport property. Moreover, a layer containing a composite material of the organic compound and the metal oxide may be combined with a transparent conductive film.

The light-emitting element **331** having such a structure is unlikely to suffer the problem of energy transfer, quenching, or the like and has an expanded choice of materials, and thus can easily have both high emission efficiency and a long lifetime. Moreover, it is easy to obtain phosphorescence from one light-emitting layer and fluorescence from the other light-emitting layer.

The charge generation layer **320***a* has a function of injecting electrons to one of the EL layers **320** that is in contact with the charge generation layer **320***a* and a function of injecting holes to the other EL layer **320** that is in contact with the charge generation layer **320***a*, when voltage is applied between the electrode **318** and the electrode **322**.

The light-emitting element **331** illustrated in FIG. **51**B can provide a variety of emission colors by changing the type of the light-emitting substance used for the EL layer **320**. In addition, a plurality of light-emitting substances emitting light of different colors may be used as the light-emitting substances, whereby light emission having a broad spectrum or white light emission can be obtained.

In the case of obtaining white light emission using the light-emitting element **331** illustrated in FIG. **51**B, as for the combination of a plurality of EL layers, a structure for emitting white light including red light, green light, and blue light may be used; for example, the structure may include a light-emitting layer containing a blue fluorescent substance as a light-emitting substance and a light-emitting layer containing red and green phosphorescent substances as light-emitting substances. Alternatively, a structure including a light-emitting layer emitting red light, a light-emitting layer emitting green light, and a light-emitting layer emitting blue light may be employed. Further alternatively, with a structure including light-emitting layers emitting light of complementary colors, white light emission can be obtained. In a stacked-layer element including two light-emitting layers in which light emitted from one of the light-emitting layers and light emitted from the other light-emitting layer have complementary colors to each other, the combinations of colors are as follows: blue and yellow, blue-green and red, and the like.

Note that in the structure of the above-described stacked-layer element, by providing the charge generation layer between the stacked light-emitting layers, the element can have a long lifetime in a high-luminance region while keeping the current density low. In addition, the voltage drop due to the resistance of the electrode material can be reduced, whereby uniform light emission in a large area is possible.

With a micro optical resonator (also referred to as micro-cavity) structure which allows light emitted from the EL layer **117** to resonate, lights with different wavelengths and narrowed spectra can be extracted even when one EL layer **117** is used for different light-emitting elements **125**.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

Embodiment 8

In this embodiment, examples of an electronic device including the display device of one embodiment of the present invention are described with reference to drawings.

Specific examples of the electronic device that uses the display device of one embodiment of the present invention are as follows: display devices of televisions, monitors, and the like, lighting devices, desktop and laptop personal computers, word processors, image reproduction devices which reproduce still images and moving images stored in recording media such as digital versatile discs (DVDs), portable CD players, radios, tape recorders, headphone stereos, stereos, table clocks, wall clocks, cordless phone handsets, transceivers, mobile phones, car phones, portable game machines, tablet terminals, stationary game machines such as pachinko machines, calculators, portable information terminals, electronic notebooks, e-book readers, electronic translators, audio input devices, video cameras, digital still cameras, electric shavers, high-frequency heating appliances such as microwave ovens, electric rice cookers, electric washing machines, electric vacuum cleaners, water heaters, electric fans, hair dryers, air-conditioning systems such as air conditioners, humidifiers, and dehumidifiers, dishwashers, dish dryers, clothes dryers, futon dryers, electric refrigerators, electric freezers, electric refrigerator-freezers, freezers for preserving DNA, flashlights, electrical tools such as a chain saw, smoke detectors, and medical equipment such as dialyzers. Other examples are as follows: industrial equipment such as guide lights, traffic lights, conveyor belts, elevators, escalators, industrial robots, power storage systems, and power storage devices for leveling the amount of power supply and smart grid. In addition, moving objects and the like driven by electric motors using power from a power storage unit are also included in the category of electronic devices. Examples of the moving objects include electric vehicles (EV), hybrid electric vehicles (HEV) which include both an internal-combustion engine and a motor, plug-in hybrid electric vehicles (PHEV), tracked vehicles in which caterpillar tracks are substituted for wheels of these vehicles, motorized bicycles including motor-assisted bicycles, motorcycles, electric wheelchairs, golf carts, boats, ships, submarines, helicopters, aircrafts, rockets, artificial satellites, space probes, planetary probes, and spacecrafts.

In particular, as examples of electronic devices including the display device of one embodiment of the present invention, the following can be given: television devices (also referred to as televisions or television receivers), monitors of computers or the like, digital cameras, digital video cameras, digital photo frames, mobile phones (also referred to as cellular phones or mobile phone devices), portable game machines, portable information terminals, audio reproducing devices, large game machines such as pachinko machines, and the like.

In addition, a lighting device or a display device can be incorporated along a curved inside/outside wall surface of a house or a building or a curved interior/exterior surface of a car.

FIG. **52**A is an example of a mobile phone (e.g., a smartphone). A mobile phone **7400** includes a display portion **7402** that is incorporated in a housing **7401**. The mobile phone **7400** further includes operation buttons **7403**, an external connection port **7404**, a speaker **7405**, a microphone **7406**, and the like. The mobile phone **7400** is manufactured using the display device of one embodiment of the present invention for the display portion **7402**.

The mobile phone **7400** illustrated in FIG. **52**A includes a touch sensor in the display portion **7402**. When the display portion **7402** is touched with a finger or the like, data can be input into the mobile phone **7400**. Furthermore, operations such as making a call and inputting a letter can be performed by touch on the display portion **7402** with a finger or the like.

With the operation buttons **7403**, power ON/OFF can be switched. In addition, types of images displayed on the display portion **7402** can be switched; for example, switching images from a mail creation screen to a main menu screen.

Here, the display portion **7402** includes the display device of one embodiment of the present invention. Thus, the mobile phone can have a curved display portion and high reliability.

FIG. **52**B illustrates an example of a mobile phone such as a smartphone. A mobile phone **7410** includes a housing **7411** provided with a display portion **7412**, a microphone **7416**, a speaker **7415**, a camera **7417**, an external connection portion **7414**, an operation button **7413**, and the like. The display device of one embodiment of the present invention can be used for the display portion **7412** with a curved surface.

When the display portion **7412** of the cellular phone **7410** illustrated in FIG. **52**B is touched with a finger or the like, data can be input to the cellular phone **7410**. Operations such as making a call and creating an e-mail can be performed by touching the display portion **7412** with a finger or the like.

There are mainly three screen modes of the display portion **7412**. The first mode is a display mode mainly for displaying an image. The second mode is an input mode mainly for inputting data such as characters. The third mode is a display-and-input mode in which two modes of the display mode and the input mode are combined.

For example, in the case of making a call or creating e-mail, a character input mode mainly for inputting characters is selected for the display portion **7412** so that characters displayed on the screen can be input. In this case, it is preferable to display a keyboard or number buttons on almost the entire screen of the display portion **7412**.

The screen modes can be switched depending on the kind of images displayed on the display portion **7412**. For example, when a signal of an image displayed on the display portion is a signal of moving image data, the screen mode may be switched to the display mode. When the signal is a signal of text data, the screen mode may be switched to the input mode.

In the input mode, if a touch sensor in the display portion **7412** judges that the input by touch on the display portion **7412** is not performed for a certain period, the screen mode may be switched from the input mode to the display mode.

When a detection device including a sensor (e.g., a gyroscope or an acceleration sensor) is provided inside the mobile phone **7410**, the direction of display on the screen of the display portion **7412** can be automatically changed by determining the orientation of the mobile phone **7410** (whether the mobile phone is placed horizontally or vertically). Furthermore, the direction of display on the screen can be changed by touch on the display portion **7412** or operation with the operation button **7413** of the housing **7411**.

FIG. **52**C is an example of a wristband-type display device. A portable display device **7100** includes a housing **7131**, a display portion **7102**, operation buttons **7103**, and a transceiver **7104**.

The portable display device **7100** can receive a video signal with the transceiver **7104** and can display the received video on the display portion **7102**. In addition, with the transceiver **7104**, the portable display device **7100** can send an audio signal to another receiving device.

With the operation button **7103**, power ON/OFF, switching displayed videos, adjusting volume, and the like can be performed.

Here, the display portion **7102** includes the display device of one embodiment of the present invention. Thus, the portable display device can have a curved display portion and high reliability.

FIGS. **52**D to **52**F show examples of lighting devices. Lighting devices **7200**, **7210**, and **7220** each include a stage **7201** provided with an operation switch **7203** and a light-emitting portion supported by the stage **7201**.

The lighting device **7200** illustrated in FIG. **52**D includes a light-emitting portion **7202** with a wave-shaped light-emitting surface and thus is a good-design lighting device.

A light-emitting portion **7212** included in the lighting device **7210** illustrated in FIG. **52**E has two convex-curved light-emitting portions symmetrically placed. Thus, light radiates from the lighting device **7210** in all directions.

The lighting device **7220** illustrated in FIG. **52**F includes a concave-curved light-emitting portion **7222**. This is suitable for illuminating a specific range because light emitted from the light-emitting portion **7222** is collected to the front of the lighting device **7220**.

The light-emitting portion included in each of the lighting devices **7200**, **7210**, and **7220** is flexible; thus, the light-emitting portion can be fixed on a plastic member, a movable frame, or the like so that an emission surface of the light-emitting portion can be curved freely depending on the intended use.

The light-emitting portions included in the lighting devices **7200**, **7210**, and **7220** each include the display device of one embodiment of the present invention. Thus, the light-emitting portions can be curved or bent into any shape and the lighting devices can have high reliability.

FIG. **53**A shows an example of a portable display device. A display device **7300** includes a housing **7301**, a display portion **7302**, operation buttons **7303**, a display portion pull **7304**, and a control portion **7305**.

The display device **7300** includes the rolled flexible display portion **7302** in the cylindrical housing **7301**.

The display device **7300** can receive a video signal with the control portion **7305** and can display the received video on the display portion **7302**. In addition, a power storage device is included in the control portion **7305**. Moreover, a connector may be included in the control portion **7305** so that a video signal or power can be supplied directly.

With the operation buttons **7303**, power ON/OFF, switching of displayed videos, and the like can be performed.

FIG. **53**B illustrates a state where the display portion **7302** is pulled out with the display portion pull **7304**. Videos can be displayed on the display portion **7302** in this state. Furthermore, the operation buttons **7303** on the surface of the housing **7301** allow one-handed operation.

Note that a reinforcement frame may be provided for an edge of the display portion **7302** in order to prevent the display portion **7302** from being curved when pulled out.

Note that in addition to this structure, a speaker may be provided for the housing so that sound is output with an audio signal received together with a video signal.

The display portion **7302** includes the display device of one embodiment of the present invention. Thus, the display portion **7302** is a display device which is flexible and highly reliable, which makes the display device **7300** lightweight and highly reliable.

FIGS. **54**A and **54**B show a double foldable tablet terminal **9600** as an example. FIG. **54**A illustrates the tablet terminal **9600** which is unfolded. The tablet terminal **9600** includes a housing **9630**, a display portion **9631**, a display mode switch **9626**, a power switch **9627**, a power-saving mode switch **9625**, a clasp **9629**, and an operation switch **9628**.

The housing **9630** includes a housing **9630***a* and a housing **9630***b*, which are connected with a hinge portion **9639**. The hinge portion **9639** makes the housing **9630** double foldable.

The display portion **9631** is provided on the housing **9630***a*, the housing **9630***b*, and the hinge portion **9639**. By the use of the display device disclosed in this specification and the like for the display portion **9631**, the tablet terminal in which the display portion **9631** is foldable and which has high reliability can be provided.

Part of the display portion **9631** can be a touchscreen region **9632** and data can be input when a displayed operation key **9638** is touched. A structure can be employed in which half of the display portion **9631** has only a display function and the other half has a touchscreen function. The whole display portion **9631** may have a touchscreen function. For example, keyboard buttons may be displayed on the entire region of the display portion **9631** so that the display portion **9631** can be used as a data input terminal.

The display mode switch **9626** can switch the display between a portrait mode and a landscape mode, and between monochrome display and color display, for example. The power-saving mode switch **9625** can control display luminance in accordance with the amount of external light in use of the tablet terminal detected by an optical sensor incorporated in the tablet terminal. Another detection device including a sensor for detecting inclination, such as a gyroscope or an acceleration sensor, may be incorporated in the tablet terminal, in addition to the optical sensor.

FIG. **54**B illustrates the tablet terminal **9600** which is folded. The tablet terminal **9600** includes the housing **9630**, a solar cell **9633**, and a charge and discharge control circuit **9634**. As an example, FIG. **54**B illustrates the charge and discharge control circuit **9634** including a battery **9635** and a DC-DC converter **9636**.

By including the display device of one embodiment of the present invention, the display portion **9631** is foldable. Since the tablet terminal **9600** is double foldable, the housing **9630** can be closed when the tablet terminal is not in use, for example; thus, the tablet terminal is highly portable. Moreover, since the display portion **9631** can be protected when the housing **9630** is closed, the tablet terminal can have high durability and high reliability for long-term use.

The tablet terminal illustrated in FIGS. **54**A and **54**B can have other functions such as a function of displaying various kinds of data (e.g., a still image, a moving image, and a text image), a function of displaying a calendar, a date, the time, or the like on the display portion, a touch-input function of operating or editing the data displayed on the display portion by touch input, and a function of controlling processing by various kinds of software (programs).

The solar cell **9633** provided on a surface of the tablet terminal can supply power to the touchscreen, the display portion, a video signal processing portion, or the like. Note that the solar cell **9633** is preferably provided on one or both surfaces of the housing **9630**, in which case the battery **9635** can be charged efficiently. When a lithium ion battery is used as the battery **9635**, there is an advantage of downsizing or the like.

The structure and operation of the charge and discharge control circuit **9634** illustrated in FIG. **54**B is described with reference to a block diagram of FIG. **54**C. FIG. **54**C illustrates the solar cell **9633**, the battery **9635**, the DC-DC converter **9636**, a converter **9637**, switches SW**1** to SW**3**, and the display portion **9631**. The battery **9635**, the DC-DC converter **9636**, the converter **9637**, and the switches SW**1** to SW**3** correspond to the charge and discharge control circuit **9634** illustrated in FIG. **54**B.

First, description is made on an example of the operation in the case where power is generated by the solar cell **9633** with the use of external light. The voltage of the power generated by the solar cell is raised or lowered by the DC-DC converter **9636** so as to be voltage for charging the battery **9635**. Then, when power from the solar cell **9633** is used for the operation of the display portion **9631**, the switch SW**1** is turned on and the voltage of the power is raised or lowered by the converter **9637** so as to be voltage needed for the display portion **9631**. When images are not displayed on the display portion **9631**, the switch SW**1** is turned off and the switch SW**2** is turned on so that the battery **9635** is charged.

Although the solar cell **9633** is described as an example of a power generation unit, the power generation unit is not particularly limited, and the battery **9635** may be charged by another power generation unit such as a piezoelectric element or a thermoelectric conversion element (Peltier element). For example, the battery **9635** may be charged using a non-contact power transmission module that transmits and receives power wirelessly (without contact) or using another charge unit in combination.

It is needless to say that one embodiment of the present invention is not limited to the above-described electronic devices and lighting devices as long as the display device of one embodiment of the present invention is included.

FIGS. **55**A to **55**C illustrate a foldable portable information terminal **9310** as an example of an electronic device. FIG. **55**A illustrates the portable information terminal **9310** that is opened. FIG. **55**B illustrates the portable information terminal **9310** that is being opened or being folded. FIG. **55**C illustrates the portable information terminal **9310** that is folded. The portable information terminal **9310** includes a display panel **9316**, housings **9315**, and hinges **9313**. The portable information terminal **9310** is highly portable when folded. When the portable information terminal **9310** is opened, a seamless large display region is obtained; thus, the display image is highly browsable.

The display panel **9316** included in the portable information terminal **9310** is supported by the three housings **9315** joined together by the hinges **9313**. The display panel **9316** can be folded at the hinges **9313**. The portable information terminal **9310** can be reversibly changed in shape from an opened state to a folded state. The display device of one embodiment of the present invention can be used for the display panel **9316**. For example, a display device that can be bent with a radius of curvature of greater than or equal to 1 mm and less than or equal to 150 mm can be used. The display panel **9316** may include a touch sensor.

Note that in one embodiment of the present invention, a sensor that senses whether the display panel **9316** is in a folded state or an unfolded state may be used. The operation of a folded portion (or a portion that becomes invisible by a user by folding) of the display panel **9316** may be stopped by a control device through the acquisition of data indicating the folded state of the touch panel. Specifically, display of the portion may be stopped. In the case where a touch sensor is included, detection by the touch sensor may be stopped.

Similarly, the control device of the display panel **9316** may acquire data indicating the unfolded state of the display panel **9316** to resume displaying and sensing by the touch sensor.

FIGS. **55**D and **55**E each illustrate a foldable portable information terminal **9320**. FIG. **55**D illustrates the portable information terminal **9320** that is folded so that a display portion **9322** is on the outside. FIG. **55**E illustrates the portable information terminal **9320** that is folded so that the display portion **9322** is on the inside. When the portable information terminal **9320** is not used, the portable information terminal **9320** is folded so that a non-display portion **9325** faces the outside, whereby the display portion **9322** can be prevented from being contaminated or damaged. The display device of one embodiment of the present invention can be used for the display portion **9322**.

FIG. **55**F is a perspective view illustrating an external shape of a portable information terminal **9330**. FIG. **55**G is a top view of the portable information terminal **9330**. FIG. **55**H is a perspective view illustrating an external shape of a portable information terminal **9340**.

The portable information terminals **9330** and **9340** each function as, for example, one or more of a telephone set, a notebook, and an information browsing system. Specifically, the portable information terminals **9330** and **9340** each can be used as a smartphone.

The portable information terminals **9330** and **9340** can display characters and image information on their plurality of surfaces. For example, one or more operation buttons **9339** can be displayed on the front surface (FIG. **55**F). In addition, information **9337** indicated by dashed rectangles can be displayed on the top surface (FIG. **55**G) or on the side surface (FIG. **55**H). Examples of the information **9337** include notification from a social networking service (SNS), display indicating reception of an e-mail or an incoming call, the title of an e-mail or the like, the sender of an e-mail or the like, the date, the time, remaining battery, and the reception strength of an antenna. Alternatively, the operation buttons **9339**, an icon, or the like may be displayed in place of the information **9337**. Although FIGS. **55**F and **55**G illustrate an example in which the information **9337** is displayed at the top and side surfaces, one embodiment of the present invention is not limited thereto. The information **9337** may be displayed, for example, on the bottom or rear surface.

For example, a user of the portable information terminal **9330** can see the display (here, the information **9337**) with the portable information terminal **9330** put in a breast pocket of his/her clothes.

Specifically, a caller's phone number, name, or the like of an incoming call is displayed on the front surface of the portable information terminal **9330**. Thus, the user can see the display without taking out the portable information terminal **9330** from the pocket and decide whether to answer the call.

The display device of one embodiment of the present invention can be used for a display portion **9333** mounted in each of a housing **9335** of the portable information terminal **9330** and a housing **9336** of the portable information terminal **9340**. One embodiment of the present invention can provide a highly reliable display device having a curved display portion with a high yield.

As in a portable information terminal **9345** illustrated in FIG. **55**I, data may be displayed on three or more surfaces. Here, data **9355**, data **9356**, and data **9357** are displayed on different surfaces.

The display device of one embodiment of the present invention can be used for a display portion **9358** included in a housing **9354** of the portable information terminal **9345**. One embodiment of the present invention can provide a highly reliable display device having a curved display portion with a high yield.

The display device of one embodiment of the present invention is resistant to external impact and unlikely to be broken. An electronic device including the display device of one embodiment of the present invention is resistant to external impact and unlikely to be broken.

FIG. **56**A illustrates a portable game machine including a housing **7131**, a housing **7132**, a display portion **7133**, a display portion **7134**, a microphone **7105**, speakers **7106**, an operation key **7107**, a stylus **7108**, and the like. The display device of one embodiment of the present invention can be used for the display portion **7133** or the display portion **7134**. When the display device of one embodiment of the present invention is used as the display portion **7133** or **7134**, it is possible to provide a portable game machine whose display quality is unlikely to be decreases due to a crack. Although the portable game machine illustrated in FIG. **56**A includes two display portions, the display portion **7133** and the display portion **7134**, the number of display portions is not limited to two.

FIG. **56**B illustrates a smart watch, which includes a housing **7332**, a display portion **7334**, operation buttons **7311** and **7312**, a connection terminal **7313**, a band **7321**, a clasp **7322**, and the like. The display device according to one embodiment of the present invention can be used for the display portion **7334**.

FIG. **56**C illustrates a portable information terminal, which includes a display portion **7502** incorporated in a housing **7501**, operation buttons **7503**, an external connection port **7504**, a speaker **7505**, a microphone **7506**, and the like. The display device of one embodiment of the present invention can be used for the display portion **7502**.

FIG. **56**D illustrates a video camera including a first housing **7701**, a second housing **7702**, a display portion **7703**, operation keys **7704**, a lens **7705**, a joint **7706**, and the like. The operation keys **7704** and the lens **7705** are provided for the first housing **7701**, and the display portion **7703** is provided for the second housing **7702**. The first housing **7701** and the second housing **7702** are connected to each other with the joint **7706**, and the angle between the first housing **7701** and the second housing **7702** can be changed with the joint **7706**. Images displayed on the display portion **7703** may be switched in accordance with the angle at the joint **7706** between the first housing **7701** and the second housing **7702**. The imaging device of one embodiment of the present invention can be used in a portion corresponding to a focus of the lens **7705**. The display device according to one embodiment of the present invention can be used for the image display portion **7703**.

FIG. **57**A is an external view of an automobile **9700**. FIG. **57**B illustrates a driver's seat of the automobile **9700**. The automobile **9700** includes a car body **9701**, wheels **9702**, a dashboard **9703**, lights **9704**, and the like. The display device of one embodiment of the present invention can be used in a display portion or the like of the automobile **9700**. For example, the display device of one embodiment of the present invention can be used in display portions **9710** to **9715** illustrated in FIG. **57**B.

The display portion **9710** and the display portion **9711** are display devices provided in an automobile windshield. The display device of one embodiment of the present invention can be a see-through display device, through which the opposite side can be seen, by using a light-transmitting conductive material for its electrodes. Such a see-through display device does not hinder driver's vision during driving the automobile **9700**. Therefore, the display device of one embodiment of the present invention can be provided in the windshield of the automobile **9700**. Note that in the case where a transistor or the like for driving the display device is provided in the display device, a transistor having light-transmitting properties, such as an organic transistor using an organic semiconductor material or a transistor using an oxide semiconductor, is preferably used.

The display portion **9712** is a display device provided on a pillar portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9712**, whereby the view hindered by the pillar portion can be compensated. The display portion **9713** is a display device provided on the dashboard. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9713**, whereby the view hindered by the dashboard can be compensated. That is, by displaying an image taken by an imaging unit provided on the outside of the automobile, blind areas can be eliminated and safety can be increased. Displaying an image to compensate for the area which a driver cannot see, makes it possible for the driver to confirm safety easily and comfortably.

FIG. **58** illustrates the inside of a car in which bench seats are used for a driver seat and a front passenger seat. A display portion **9721** is a display device provided in a door portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9721**, whereby the view hindered by the door can be compensated. A display portion **9722** is a display device provided in a steering wheel. A display portion **9723** is a display device provided in the middle of a seating face of the bench seat. Note that the display device can be used as a seat heater by providing the display device on the seating face or backrest and by using heat generation of the display device as a heat source.

The display portion **9714**, the display portion **9715**, and the display portion **9722** can provide a variety of kinds of information such as navigation data, a speedometer, a tachometer, a mileage, a fuel meter, a gearshift indicator, and air-condition setting. The content, layout, or the like of the display on the display portions can be changed freely by a user as appropriate. The information listed above can also be displayed on the display portions **9710** to **9713**, **9721**, and **9723**. The display portions **9710** to **9715** and **9721** to **9723** can, also be used as lighting devices. The display portions **9710** to **9715** and **9721** to **9723** can also be used as heating devices.

This embodiment can be implemented in an appropriate combination with any of the structures described in the other embodiments.

This application is based on Japanese Patent Application serial no. 2014-169167 filed with Japan Patent Office on Aug. 22, 2014 and Japanese Patent Application serial no. 2014-206913 filed with Japan Patent Office on Oct. 8, 2014, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A method for fabricating a display device comprising a first substrate comprising a first surface and a second surface that faces the first surface, a second substrate comprising a third surface and a fourth surface that faces the third surface, and a first layer, the method comprising the steps of:

a first step of forming a display element over the first surface;

a second step of overlapping the first substrate and the second substrate so that the first surface and the third surface face each other;

a third step of forming a spacer to be in contact with at least a part of the second surface, at least a part of the fourth surface, at least a side surface of the first substrate, and at least a side surface of the second substrate;

a fourth step of disposing the first substrate, the second substrate, and the spacer into a metallic mold;

a fifth step of putting a filler into the metallic mold; and

a sixth step of curing the filler, thereby forming the first layer,

wherein the first layer has a smaller Young's modulus than the first substrate and the second substrate.

2. The method for fabricating a display device, according to claim **1**, wherein the spacer and the first layer have a same light transmittance.

3. The method for fabricating a display device, according to claim **1**, wherein the spacer and the first layer have a same refractive index.

4. The method for fabricating a display device, according to claim **1**, wherein the display element is a light-emitting element.

5. The method for fabricating a display device, according to claim **1**, wherein the first layer is silicone rubber.

6. The method for fabricating a display device, according to claim **1**, wherein the first substrate and the second substrate overlap each other with a transistor positioned therebetween.

7. The method for fabricating a display device, according to claim **6**, wherein in the transistor, an oxide semiconductor is used for a semiconductor layer where a channel is formed.

8. A method for fabricating a display device comprising a first substrate comprising a first surface and a second surface that faces the first surface, a second substrate comprising a third surface and a fourth surface that faces the third surface, and a first layer, the method comprising the steps of:

a first step of forming a display element over the first surface;

a second step of overlapping the first substrate and the second substrate so that the first surface and the third surface face each other;

a third step of forming a spacer to be in contact with at least a part of the second surface, at least apart of the fourth surface, at least a side surface of the first substrate, and at least a side surface of the second substrate;

a fourth step of disposing the first substrate, the second substrate, and the spacer into a metallic mold;

a fifth step of putting a filler into the metallic mold; and

a sixth step of curing the filler, thereby forming the first layer,

wherein the Young's modulus of each of the first substrate and the second substrate is larger than or equal to 1 GPa and smaller than or equal to 100 GPa.

9. The method for fabricating a display device, according to claim **8**, wherein the spacer and the first layer have a same light transmittance.

10. The method for fabricating a display device, according to claim **8**, wherein the spacer and the first layer have a same refractive index.

11. The method for fabricating a display device, according to claim **8**, wherein the display element is a light-emitting element.

12. The method for fabricating a display device, according to claim **8**, wherein the first layer is silicone rubber.

13. The method for fabricating a display device, according to claim **8**, wherein the first substrate and the second substrate overlap each other with a transistor positioned therebetween.

14. The method for fabricating a display device, according to claim **13**, wherein in the transistor, an oxide semiconductor is used for a semiconductor layer where a channel is formed.

15. A method for fabricating a display device comprising a first substrate comprising a first surface and a second surface that faces the first surface, a second substrate comprising a third surface and a fourth surface that faces the third surface, and a first layer, the method comprising the steps of:

a first step of forming a display element over the first surface;

a second step of overlapping the first substrate and the second substrate so that the first surface and the third surface face each other;

a third step of forming a spacer to be in contact with at least a part of the second surface, at least a part of the fourth surface, at least a side surface of the first substrate, and at least a side surface of the second substrate;

a fourth step of disposing the first substrate, the second substrate, and the spacer into a metallic mold;

a fifth step of putting a filler into the metallic mold; and

a sixth step of curing the filler, thereby forming the first layer,

wherein the Young's modulus of the first layer is smaller than or equal to one fiftieth of the Young's modulus of each of the first substrate and the second substrate.

16. The method for fabricating a display device, according to claim **15**, wherein the spacer and the first layer have a same light transmittance.

17. The method for fabricating a display device, according to claim **15**, wherein the spacer and the first layer have a same refractive index.

18. The method for fabricating a display device, according to claim **15**, wherein the display element is a light-emitting element.

19. The method for fabricating a display device, according to claim **15**, wherein the first layer is silicone rubber.

20. The method for fabricating a display device, according to claim **15**, wherein the first substrate and the second substrate overlap each other with a transistor positioned therebetween.

21. The method for fabricating a display device, according to claim **20**, wherein in the transistor, an oxide semiconductor is used for a semiconductor layer where a channel is formed.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,843,017 B2
APPLICATION NO. : 14/826585
DATED : December 12, 2017
INVENTOR(S) : Yuichi Yanagisawa and Takuya Kawata

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 55, Line 62, Claim 8; Change “least apart of” to --least a part of--.

Signed and Sealed this
Thirteenth Day of March, 2018

Andrei Iancu
Director of the United States Patent and Trademark Office